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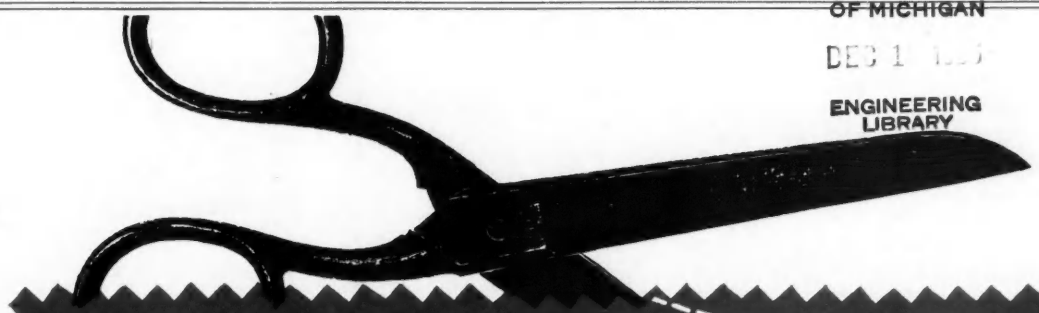

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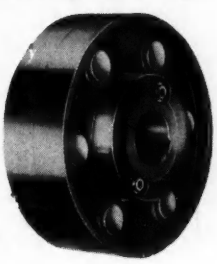

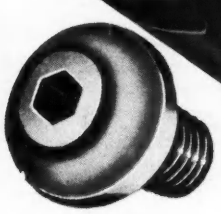

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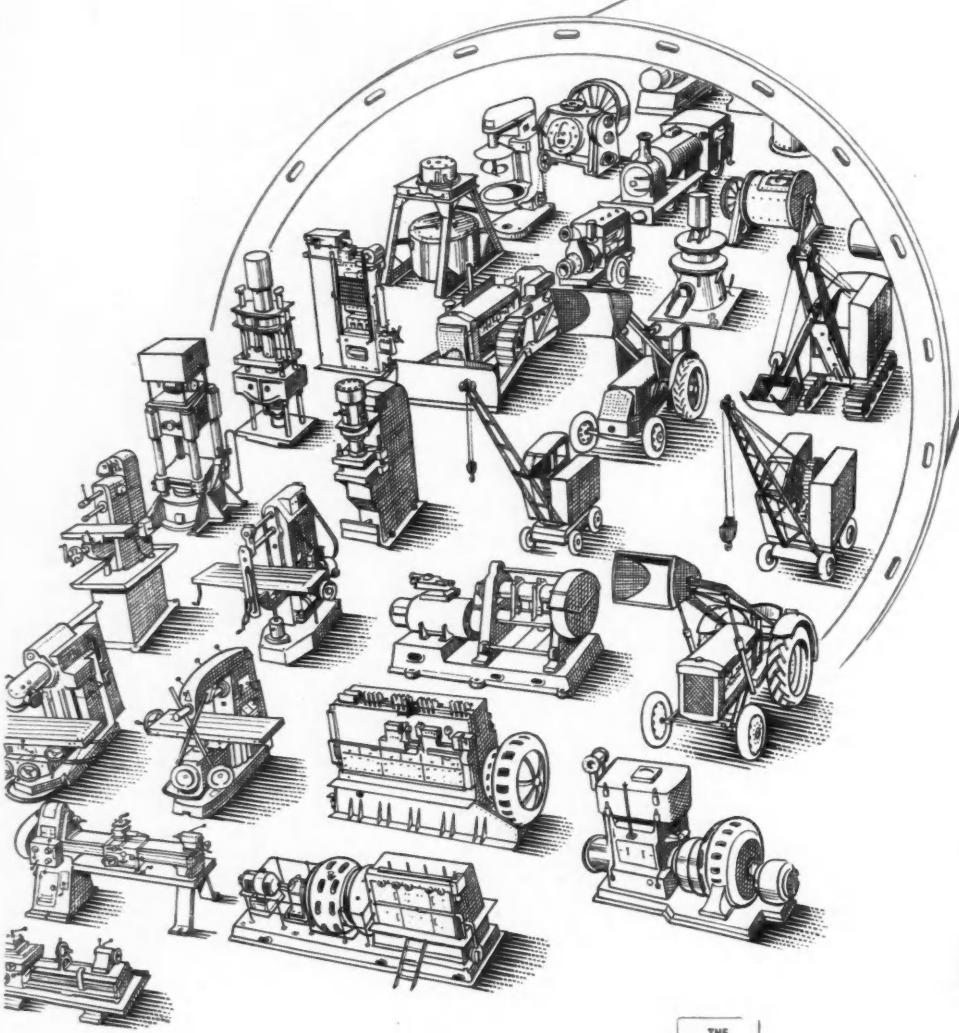

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THE ENGINEER

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DIESEL ENGINES FOR RAIL TRACTION

In introducing a paper, " The Special Requirements of Diesel Engines for Rail Traction," read by him before the Diesel Engineers and Users Association last week, Mr. J. S. Tritton remarked that " There is a well-founded belief among locomotive engineers that a piece of machinery or equipment which behaves perfectly satisfactorily in stationary or marine service develops all sorts of unexpected idiosyncracies when put into a locomotive." Mr. Tritton is exceptionally well-qualified to call attention to this belief and railway engineers will not fail to study his very interesting paper, the object of which is " to show in some measure how the special requirements of railway service differ from those of stationary and marine practice, how far these requirements can be specified and how they are being met by designers and manufacturers." Not long ago, Mr. R. C. Bond, chief mechanical engineer, British Railways Division of the British Transport Commission, remarked how " the fundamental difference between a steam and a diesel locomotive is this—that the relationship between the time required to find a defect and put it right is exactly reversed in the two cases—that it takes five minutes to find what is wrong with a steam locomotive and two days to put it right ; in the diesel locomotive it takes two days to find what is wrong and five minutes to put it right ! Mr. Bond further observed how " it seems difficult to define exactly the rating which should be assigned to diesel engines under traction conditions to ensure reliable service at reasonable maintenance cost."

Studying Mr. Tritton's paper, we look with special curiosity for what he has to say on this matter of engine rating and we are not surprised to find that he describes it as " the vital question." Quoting the ratings defined by the British Standards Committee and now—or shortly—to be current among us, he points out, relatively to the definitions for normal load and overload, respectively, that both definitions depend on what is called the " useful output," this being defined as the mechanical output supplied by the engine for traction, auxiliaries and cooling. " The ' rated output,' however " (we quote from Mr. Tritton's paper), " is ' the useful output ' assigned to the engine by the manufacturer. So, in rating his engine for any particular service, the engine manufacturer will have to come to the best agreement he can with both the locomotive builder and the purchaser on what periods between overhauls will best fit in with the service." This certainly suggests, *inter alia*, the relationship between rating and maintenance, indeed, it would not be too much to say that the question of availability (on which so much stress is rightly placed) is inseparably connected with the question of maintenance. It is here that the American Railroads have, by that collaboration which Mr. Tritton describes and so strongly commends, pointed the way to operational success with diesel locomotives. They have developed work-cycles which, related to specific services, have imparted real meaning to the word " availability." By establishing schedules of work ensuring that after a given trip mileage the mechanism will be verified correct and that all necessary heavy running repairs will be dealt with systematically at the end of a fixed period of service, diesel passenger locomotives are operated between shoppings for an average of about 350,000 miles. The build-up of experience in respect of the various components is, of course, greatly facilitated by the high degree of locomotive standardisation established in the United States. This standardisation enables the work of renewal and reconditioning to proceed with precision and rapidity in the hands of men familiar with the individual items. The maintenance schedules are themselves eloquent witnesses of the relative propensity to wear as reflected by the various components, ranging as they do from engine main bearings to steam generator coils and headlights.

The effect of the railway loading gauge in restricting the overall dimensions to which a locomotive can be built is more extreme here than in America. But, while the space available in American practice is—as pointed out by Mr. Tritton—much greater than that obtaining in Great Britain, the Americans must cope with problems of long continuous gradients and of loss of power from altitude the like of which are quite unknown here. Standard gauge main line railroads in the United States go to altitudes exceeding 10,000ft and any British railwayman travelling, say, from Salt Lake City, Utah, to Denver, Colorado, or from Needles, California to Syracuse, Kansas, both on trans-continental

main lines, must gladly agree that no such traction problems are encountered within our islands. Mr. Tritton mentions the development of the diesel railcar, which, in its comparatively wide range of application, is playing an important part in impressing a "new look" on our railways. One has only to see what has been and is being done in the United States and on the Continent of Europe in order to realise the influence of the oil engine upon railcar development. We read of the new six-car train for the service between Boston and New York, accommodation being provided for 468 sitting passengers. The Boston and Maine Railroad is already operating sixty-four air-conditioned stainless steel railcars in replacement of sixty-seven steam locomotives and 245 passenger vehicles. In France there have been brought into service during the past few weeks a number of particularly comfortable fast railcar trains between Paris (and other cities) and Zurich. It is satisfactory to learn, from remarks made some time ago by Mr. R. C. Bond, that in the modernisation plan for British Railways "the outstanding advantages of multiple unit trains will be fully exploited." This is no new development, and it should be remembered that British railwaymen and British manufacturers have played a prominent part in the evolution of the diesel railcar. There will certainly be general agreement about the urgent importance, for British manufacturing industry, of well-directed enterprise on the part of those responsible for the equipment and operation of the national railways. In the United States there have been, concurrently with the widespread adoption of diesel motive power, conspicuous changes in the manufacturing and purchasing practice of the railroads. The railroads (as remarked by a recent commentator) "have quit the manufacture of locomotives. This is good, because their business is railroading." Here is a hint as to how modernisation of the British railways can prove beneficial not only to those who use and operate the railways but to that export industry so important to the olvency of the nation.

AUTOMOBILE CHARACTERISTICS

Were they not modest, a group of engineers from Buffalo, U.S.A., would probably describe as a "break-through" their series of papers on automobile stability and control, presented last week to the Automobile Division of the Institution of Mechanical Engineers. The importance of their work needs no emphasis here, though it may be worth our while to commend, in particular, Mr. A. G. Fonda's "Tyre Tests and Interpretation of Experimental Data" as an exemplar among scientific papers: few engineers could fail to enjoy reading it as literature, and any who have themselves attempted to present such an address will revel in the rigour, clarity and diligence with which he regales his readers.

The programme performed by the Cornell Aeronautical Laboratory—which, be it noted, has obviously included a thorough search of the literature—has led to an, apparently, satisfactory linear theory of the dynamics of a car with fixed controls. Some account of the theory and the results upon which it is based is to be given in our columns. It has been shown to be applicable to the characteristic Anglo-Saxon automobile in which pairs of wheels remain parallel and the front wheels roll with the body. Such a car with a front engine, it appears, will at normal loads have a positive static margin, and therefore will respond to a displacement of the steering wheel with an oscillatory approach to a steady state. With a negative static margin, attained by moving the centre of gravity further back, it would reach its steady state more slowly but without overshoot; but above a certain critical speed the steady state would be undefined. The trend for the vehicle to become unstable, or to overshoot its stable state savagely, with increasing speed, is fundamental: it is associated with a fall in the damping of rotation of the car about the vertical axis, which is due to the fact that the slip angle of the tyres at a given rate of yaw becomes less and less for increasing forward speed. Only with the centre of gravity at the neutral steer point is the motion always critically damped. The characteristics of the car do not, of course, constitute the whole concern of the designers. A major factor, still inadequately understood, is the nature of the driver! That the field for speculation as to what characteristics are desired by drivers is still wide was apparent at the meeting in London. One "discusser" (the authors' expressive term) who perhaps did not expect to be taken seriously, suggested that drivers would, in time, grow to accept the "understeer" characteristics of the contemporary car.

The science of automobile handling is yet in its formative stages, and doubtless European engineers will eagerly strive to extend these concepts to their own cars, which may well not be so easily represented by linear relations. The handicap this involves becomes clear when it is realised that, in linear theory, weight transfer has no significance and a mathematical model car may have two wheels only. However, one major result has become clear already, and that is the all-pervading importance of the tyre characteristics, particularly cornering stiffness. The power of this term is indicated by the fact that the cornering coefficient at unit slip angle on a Ferrari "Monza" is about four times as high as on a saloon with cushion tyres. (The appendix comparing these cars would stand as an article on its own merits.) Increases in cornering stiffness increase the margin between "understeer" and instability, or alternatively raise the critical speed, and thus help to counter the problem of varying positions of the centre of gravity. If the car has to operate with a positive static margin, increased stiffness reduces the overshoot experienced. Thus, it is not surprising that the view was expressed that good riding qualities should be sought solely by superior suspension, and that tyres should be designed entirely for handling qualities. It is indeed attractive to speculate how many of the awkward compromises looming in the "Design Implications" of this theory could be avoided by, possibly, steel-cord tyres. But automobile handling is clearly bound to remain an empirical art so long as, to quote a member at another meeting,

"The less backward (tyre makers) are only able to supply characteristic curves when given sufficient notice."

The Engineer
100 Years Ago
(NOVEMBER 21, 1856)

"ELECTRIC TELEGRAPH ACROSS THE ATLANTIC"

"Mr. Cyrus W. Field, a New York merchant, and one of the leading promoters of the proposed Atlantic Telegraph Company, lately gave, at the Liverpool Underwriters' rooms, an exposition of the project of a submarine telegraph communication between the coast of Newfoundland and the west coast of Ireland, a distance of 1640 geographical and 1900 statute miles. Mr. Field stated, that the mode by which it was proposed to lay the cable was this—that two vessels should sail into the centre of the Atlantic, and the wires carried by each having been connected together, and the electric circuit established, one vessel would sail to Newfoundland, the other to Ireland, the cables being payed out as they proceeded. Mr. Field anticipated that the cable might be laid in a week, and that the whole business might be accomplished next year.

"He exhibited the cable which it was proposed to adopt, and which is little more than half-an-inch in diameter. The copper wire which forms the conductor consists of seven wires rolled into one; it is about an eighth of an inch in diameter, and is embedded in gutta-percha. The exterior coating of the cable is of steel wire strongly and closely twisted. Mr. Field stated that this cable was capable of transmitting 14,400 words every 24 hours; it could be manufactured and laid down at an expense of £350,000. He left it to the merchants of Liverpool to say what would be a reasonable amount to charge per word, and what amount of business might be anticipated, when they remembered that from Liverpool to New Orleans a letter could not be written and a reply received in less than forty days, while, when the telegraphic communication was open, a message would be at New Orleans (looking at the difference of time, four hours and forty-eight minutes between the two places), actually six hours before it was sent from Liverpool. (Laughter.) . . . Mr. Charles Bright, of the Magnetic Telegraph Company, stated as his firm opinion that there would be no difficulties in the electrical portion of the project."

A Seven Day Journal

"Dido" Research Reactor

A NEW research reactor known as "Dido" was formally opened at the U.K. Atomic Energy Research Establishment, Harwell, by Sir Cyril Hinshelwood, president of the Royal Society, on Wednesday, November 21. "Dido" is cooled and moderated by heavy water and the fuel elements contain highly enriched uranium. The core of the reactor is a roughly cylindrical array of twenty-five vertical boxes, each of which consists of a parallel stack of slightly curved plates of uranium-aluminium alloy. Coarse control is effected by six cadmium-sheathed "semaphore" arms pivoted to move into or out of the core between the fuel elements; in addition, there is a fine control rod. The core is contained in an aluminium tank, which, in turn, is surrounded by a graphite reflector sealed into a helium-filled stainless steel tank. Around the tank is a concrete biological shield. Heavy water is pumped from a circuit below the reactor and is forced upwards into the core tank and through the fuel elements. Heat generated in the core is transferred from the heavy water, to the secondary coolant (ordinary water) in a heat exchanger. Finally, the heat from the secondary coolant is dissipated to atmosphere in cooling towers outside the reactor building. The whole of the reactor area is enclosed in an airtight cylindrical shell which is provided with interlocked, air-lock double doors, is forced ventilated, and is designed to confine any radioactivity that may be released in the unlikely event of a failure in the pile. Several experimental holes are built into the reactor for various research requirements. Some of these holes are designed to enable sample irradiation times to be controlled accurately or to allow defined neutron beams to emerge. Two large-scale engineering pile loops can be maintained in the reactor so that fuel assemblies can be tested for advanced designs of power reactor. Some of the experimental holes are to be used for making cobalt-60 at high activity levels, for hospital and industrial use, in amounts equivalent to about 30 kg of radium per annum. "Dido" has a peak neutron flux of about 10^{14} per square centimetre per second, and a maximum heat output of 10MW, and is the most powerful research reactor in Western Europe.

Pre-Apprenticeship Training

A NEW pre-apprentice training school for the Scottish Region of British Railways was opened in Glasgow last week by Sir Ian Bolton. This is a full-time day school in which boys will be trained to meet the apprenticeship requirements of the St. Rollox and Cowlairs works and the motive power depots in Glasgow. The training to be given will provide an introduction for the boys into the new conditions they will encounter as apprentices, and by giving them systematic training in manual skill it will be possible to determine any natural aptitude likely to suit individual boys for particular trades. At the end of this initial training period a young apprentice will be able quickly to take his place in the workshop with the fundamental principles of a trade firmly established in his mind. The scheme will provide both practical and theoretical training to all entrants from the time of their engagement to the age of sixteen years, when their apprenticeship proper will begin. Under the curriculum some twenty-seven hours a week will be devoted to practical work and twelve hours to theoretical work in the classrooms. Facilities are available for training upwards of 100 boys in the school, and it is proposed to take in some thirty boys every four months. The practical work in the school is divided into four main sections—section one covers electrical and plate work, sheet metal work and coppersmithing; section two covers turning, machining, fitting and assembly work; section three covers smithing, forging, moulding and welding, and section four joinery, coach fitting, patternmaking, painting, polishing and trimming.

Motorway Scheme for Stretford–Worsley Section of Manchester Outer Ring Road

THE Lancashire County Council's scheme for building 7 miles of motorway between Stretford and Worsley to form part of the Manchester Outer Ring Road has been confirmed by Mr. Harold Watkinson, the Minister of Transport and Civil Aviation. The road will cost about £5,000,000 to build, and it will be restricted to motor traffic. It will be carried over existing main roads, but will be connected to them by slip roads at a few specially designed two-level junctions. The road will be carried over the Ship Canal on a new high-level bridge (the Barton high-level bridge), which will largely supersede the existing Barton swing bridge, where lengthy traffic delays are frequent. The building of the approach embankment on the south side of the Ship Canal has been in progress for some years. At Worsley a new bridge will carry the new road over the Bridgewater Canal. Construction of the first part of the motorway from Urmston to the Court House, Worsley, including the new Barton high-level bridge, is expected to start next spring. The details of constructional works and the individual land plans are now being prepared by the Lancashire County Council's county surveyor and bridgemaster, Mr. James Drake.

Petrol Rationing

ON Tuesday, the Minister of Fuel and Power, Mr. Aubrey Jones, announced in Parliament that the Government had decided to institute a petrol rationing scheme from December 17. Under the scheme, private motorists will be allowed a basic ration which should permit about 200 miles of motoring a month. Supplementary allowances will be granted on a "limited scale." The Minister said that in view of the continued uncertainties in the Middle East situation the Government felt that further measures were necessary to reduce oil consumption, and the broad purpose of the scheme was to make good an estimated deficit of 25 per cent in United Kingdom supplies. For public passenger transport, the Minister said that petrol and diesel fuel consumption would be reduced on average by 10 per cent, though the cuts would vary considerably according to the kind of service. For non-industrial central heating the present reduction of 10 per cent would be increased on December 1, to 33⅓ per cent on gas-diesel oil and 25 per cent on fuel oil, while for industrial purposes the present cut of 10 per cent in gas-diesel oil would be increased to 20 per cent on January 1. Minimum requirements for the railways and for coal production would be maintained. The Minister added that it was not at present proposed to increase the 10 per cent cut in fuel oil for industry, though, he said, a further reduction in fuel oil might in time become unavoidable.

Pendulum Clock Exhibition

AN exhibition to commemorate the invention of the pendulum clock three hundred years ago by Christiaan Huygens is to be opened by the Netherlands Ambassador at the Science Museum on December 4 next. The exhibition is being organised by the Science Museum and the Antiquarian Horological Society, and it will include exhibits lent by the Rijksmuseum voor Geschiedenis der Natuurwetenschappen at Leiden and the Hessisches Landesmuseum at Kassel, as well as by private collectors. Huygens' invention turned the erratic balance-controlled timekeeper of the seventeenth century into a precision instrument and was the greatest step forward in the history of time measurement since the invention of the mechanical clock. In addition to illustrating Huygens' invention exhibits will be used to trace the history of clockwork, and examples of the earliest pendulum clocks made in this country, Holland, France, Germany and Belgium, will be shown. A special working model will illustrate various scientific facts about the pendulum, and methods of compensating for variations in temperature and barometric pressure will be shown by actual examples and drawings. In connection with the exhibition, a paper by Dr. C. A. Crommelin, entitled "Huygens' Pendulum Inventions, Successful and Unsuccessful," will be presented on December 5 at the Science Museum to a joint meeting of the Antiquarian Horological Society and the British Horological Institute. The exhibition will be open to the public daily until February 24 next and its catalogue will include a report of Dr. Crommelin's lecture.

Materials Handling in Industry

THE principal speaker at the annual dinner of the Institute of Materials Handling in London last week was Mr. Harold Wilson, who said that the country was in an uncertain and serious economic position, and its industries must therefore respond to the full to the export challenge. Many firms had done much to expand their exports, but still greater efforts must be made to compete with the rapidly increasing export rates of other countries. To this end the fullest possible use must be made of scientific developments and mechanisation to promote greater productivity. Mr. Wilson pointed out that it was no use certain interests in this country rejecting automation, as other countries were adopting it to the full and the ultimate loss would be ours. The members of the Institute, he said, were doing work of prime importance for the nation in promoting savings in our economic resources by replacing manpower by mechanisation, and educating industry to adopt efficient methods of handling goods and materials. In a later speech, Mr. John R. Sharp, the national chairman of the Institute, said that a study of all aspects of materials handling was of vital importance in industrial concerns. All too often the subject of handling in factories was no one's particular responsibility, and in most cases the appointment of one man to study and develop improved methods would pay handsome dividends. On the subject of restrictive practices, to prevent the introduction of labour-saving handling plant in industry, Mr. Sharp thought that a considered approach and sensible reasoning would generally overcome any objections on the part of workers.

Commissioning of Calder Hall No. 1 Reactor

By GORDON BROWN, Ph.D., A.M.I.Mech.E.*

No. I

This is the first of two articles describing the commissioning and start-up procedure for the Calder Hall No. 1 reactor. This article covers the commissioning or proving tests on the plant prior to hand-over to the operational team who were responsible for the actual start-up, including the loading of uranium, and whose work is the subject of the second article. The works and site tests prior to the commissioning tests are only briefly mentioned, as reference has already been made to many of these in previous issues of THE ENGINEER *(October 5, 12, 19, 1956). Particulars are given of the preliminary work and organisation for the tests leading up to the issue of detailed schedules covering all aspects of the work. The tests described include the cold static pressure testing of the complete system, the bringing up to full speed of the circulators, and finally the hot dynamic test in which the lower part of the system, including reactor and heat exchanger support and circulators, are operating at their design condition. During these tests the associated plant, including control gear, charge and discharge equipment, the sampling plant equipment for burst cartridge detection, driers, filters, and the auxiliary circuit, were proved and made gastight and the shield air cooling system was balanced.*

A DESCRIPTION of the Calder Hall Reactor has already been given in some detail in earlier issues of this journal in which brief mention has been made of some of the works and site tests on certain items of plant. It is not the intention of this paper to elaborate on these and wherever possible repetition has been avoided ; for clarity, however, certain works tests leading up to the final commissioning tests are mentioned.

The start-up of a nuclear reactor may be split up into two main parts :

(1) The commissioning tests (mechanical, electrical and civil) carried out on the completed plant to prove that it has been built to the design requirements and that it is in working order. This means that on take-over by the operating team they have got a sound and reliable plant.

(2) The actual start-up procedure commencing with the loading to criticality of the fuel elements (natural uranium contained within magnesium alloy cans in the case of the Calder reactors), and on through a series of physical tests to the bringing up to the design power of the complete plant.

This article has, therefore, been split up into these two parts.

The commissioning tests of the Calder Hall No. 1 Reactor were the joint responsibility of the design office and the construction group. It was their duty to ensure that on hand over to the operations branch all equipment was functionally correct and reliable and that the complete pressure circuit was tight to the standards demanded. In order to reduce the hand-over period to a minimum and to ensure that the staff who were to operate the plant were completely familiar with it on hand over, members of the operations branch worked directly with the design and construction teams whilst others acted as independent inspectors on such procedures as the laying of the graphite moderator, the checking of the positions of the charge tubes in the top head of the pressure vessel and the shuttering of the biological shield liner tubes around the charge tubes, and in the testing for gas tightness of the completed circuits, though this did not absolve the construction group of their responsibility to meet the standards demanded.

*Deputy Chief Engineer, Thermal Reactor Design Office, Risley Headquarters.

The start-up tests were the responsibility of the operations branch assisted where necessary by staff from the design office, the research and development branch and the A.E.R.E., Harwell. The work was co-ordinated through an operations committee.

Works and Site Test Prior To The Final Commissioning Tests

The reactor vessel was pneumatically pressure tested on site following electrical stress relief of the completed shell. Heat exchangers were hydraulically tested prior to lifting into the vertical position and, after welding in of the tube banks at the thermal sleeves, a stringent CO_2 leakage test was carried out on these external welds using an infra-red gas analyser. Ductwork was hydraulically tested at works, though certain welds were not tested until the commissioning tests. These welds and all other butt welds were radio-graphed 100 per cent. A corner cascade unit had been strain gauged and tested at works in order to prove the design prior to the production line being set up. Bellows units were hydraulically tested at works and in addition a five convolution unit had been fully strain-gauged to ensure that the stress distribution was satisfactory under combined pressure and bending. This unit had also been subjected to separate fatigue tests at full temperature and pressure. Valves had been subjected to the usual hydraulic tests and in addition operational tests at full temperature and pressure, using superheated steam, followed by air leakage tests had been carried out.

The main and auxiliary circulators were tested both hydraulically and pneumatically in the usual manner and in addition specially modified works test rigs were used to determine their characteristics and to check their mechanical reliability. At site, each circulator after erection was tested on a closed loop in order to achieve the required degree of gas tightness, and to check the mechanical aspects including the stationary and running seals. The electrical equipment throughout had the usual tests, and diesel generators were fully tested at works before delivery to site.

Control mechanisms and associated electrical equipment were tested at works on a special rig built in order to determine the speed-time characteristics throughout the operational range and on shut off with gravitational fall. This was re-checked on a special test facility at site before the mechanisms were installed in the reactor.

Fuel element charge and discharge gear was fully tried at works on a special tower rig which included a representative section of the reactor, consisting of graphite moderator, charge pan, and charge tube.

The sampling plant equipment for burst cartridge detection was tested at works to only a small degree. Individual items such as the precipitators, compressors and receivers had been pressure and operationally tested, but final testing of the complete assembly remained to be done.

The Commissioning Tests

Testing of the main reactor circuits, Fig. 2, started in mid-March, 1956, and was

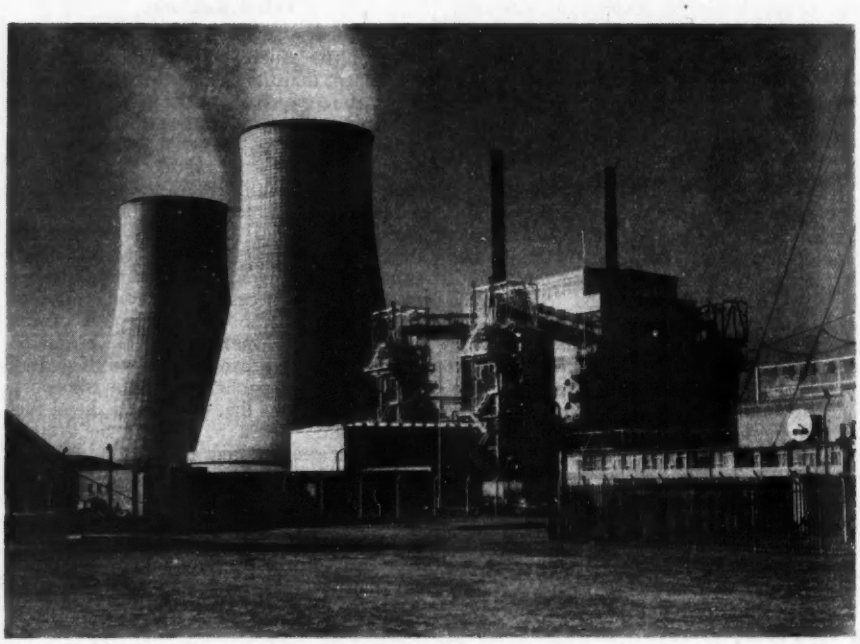

Fig. 1—Calder Hall No. 1 reactor

completed, with hand-over to the operations branch on May 17th, some six weeks ahead of the master programme set up for the project on its initiation in April, 1953. That the testing was completed satisfactorily in the short space of two months was in no small measure due to the detailed planning and carrying out of the maximum amount of test work on plant in the makers' works before delivery to site, and to the diligence of the progress and inspection engineers. In spite of this, snags were encountered on site which made heavy demands on the construction group who by this time had construction of the Calder "B" station, with two more reactors, under way. A small team of engineers within the design office were engaged full time over a period of twelve months in the preparation of schedules covering all works tests, preliminary site tests and the final commission testing. Prior to the actual commissioning tests, discussions were held between the design, construction and operations teams, the Lloyd's surveyors and the various contractors. Preliminary test schedules were drawn up and following further meetings the final schedules and programme were issued.

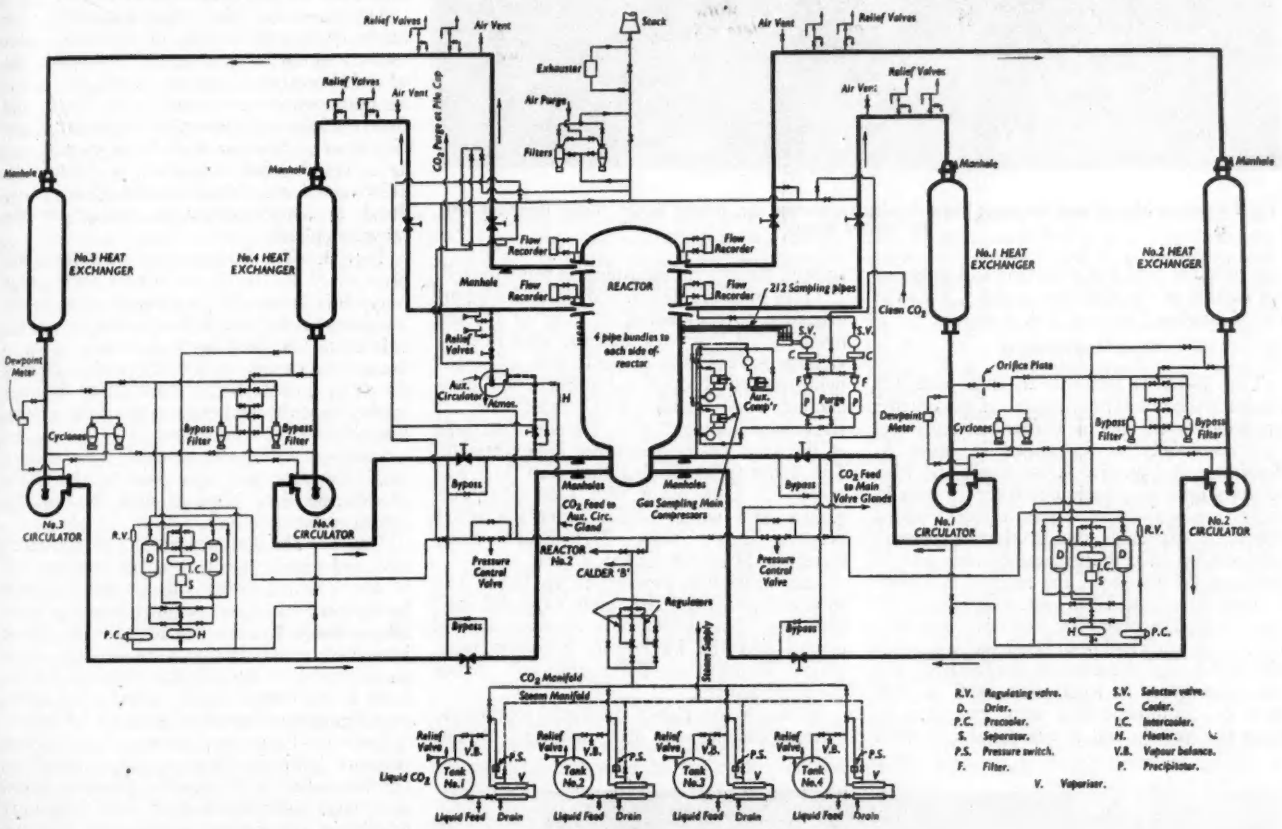

Fig. 2—Reactor circuits

Programme

The main programme was issued under eleven main headings :

(1) Cold static pressure test to 115 lb per square inch gauge (the safety valve setting) on the reactor pressure vessel up to the main duct 54in isolating valves, and to the isolating valves on the sampling plant and ancillary equipment.

(2) Cold static pressure test to 115 lb per square inch gauge on the auxiliary circulator and associated 18in ducting.

(3) Cold static pressure test to 100 lb per square inch gauge on the complete main circuit including all 54in ducting and associated small pipes up to their first isolating valves, the heat exchangers and the circulators with stationary seals in position.

(4) Cold static pressure test to 100 lb per square inch gauge on all ancillary circuits, i.e. those connecting driers, filters, cyclones, safety valves, blowdown filters, valve by-pass lines, vent lines, and sampling plant, to the main circuit.

(5) Cold dynamic test at atmospheric pressure on the complete circuit.

(6) Trials on the fuel element charge and discharge equipment.

(7) Cold dynamic test on the complete circuit at the working pressure of 100 lb per square inch gauge.

(8) Hot dynamic test on the complete circuit at 115 lb per square inch gauge and 140 deg. Cent. (284 deg. Fah.) (the normal working temperature of the circulators and lower gas duct systems) throughout the circuit. This series included tests on the following : the main circulators, Ward Leonard driving system and associated equipment, Fig. 3, the auxiliary circulator, Fig. 4, ancillary equipment such as cyclones, filters and driers, the sampling plant, the control gear, and instrumentation including all safety and trip devices. During this test, the opportunity was taken to bring on to line and commission the steam side of the heat exchangers through to the dump condenser, the cooling water system and No. 1 cooling tower.

(9) Vacuum test on the complete system to 27in Hg.

(10) Functional test on the carbon dioxide storage, Fig. 5, and evaporation plant.

(11) Flow adjustment on the induced draught shield air cooling system.

Schedules

The schedules prepared included :

(a) Organisation charts giving the staff and their responsibilities, and the names of the contractors and their representatives associated with the various parts of the plant.

(b) The detailed programme and test procedure. This was reviewed daily and a notice board was set up to advise all concerned in the test of the procedure for the day and their duties.

(c) Particulars of all items of equipment used in the tests.

(d) Circuit diagrams numbering and showing for each stage of the tests the positions of all ducts, valves, glands, seal welds, gasketted joints, duct supports, temperature and pressure connections, and strain gauges. This ensured quick and unambiguous reference to any item in the system. A chart in the control room showed the siting and position, i.e. open or closed, of all valves in the pressure circuit.

(e) Charts for the recording of results. Such items as reactor pressure and temperature, duct movements, duct support readings, and operating conditions of the circulators and electrical equipment.

The total number of schedules prepared were for works' tests 165 and for site tests 419.

Equipment

The pressurisation equipment for the above tests included : four diesel compressors each capable of delivering 240 cubic feet per minute, at pressures up to 160 lb per square inch gauge; (these were capable of charging the vessel, complete with graphite moderator, up to the main isolating valves to 100 lb per square inch gauge in approximately five hours or the entire main circuit to the same pressure in approximately fifteen hours) ; after cooler to assist the drier ; oil filter and drier to ensure than "no" oil or water vapour was introduced into the clean reactor; relief valve.

Air was used for pressure testing throughout this phase of the work. "Teepol" in water

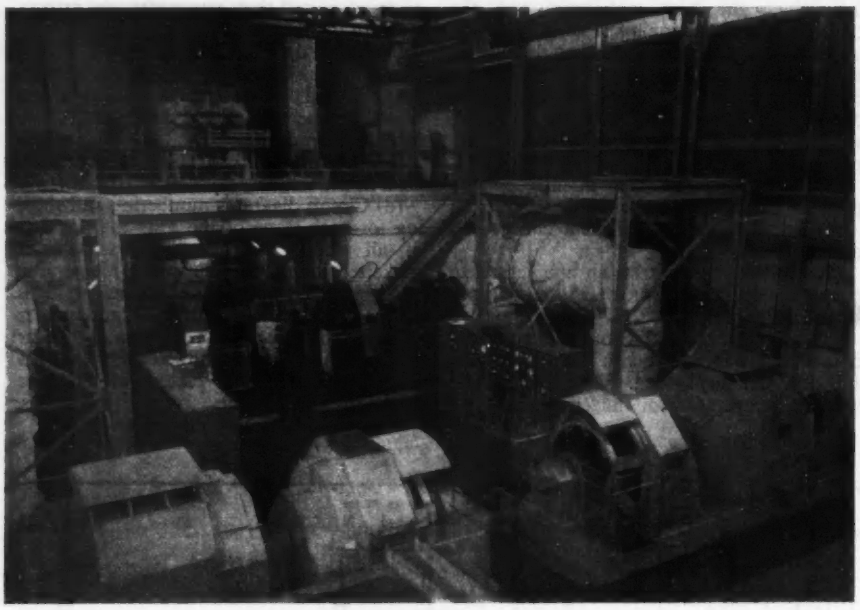

Fig. 3—General view of east circulator house showing circulators, d.c. driving motor, motor generator sets and control panels

was used for cold leak detection and glycerine with either of the frothing agents " Teepol " or " Cetavlon " for hot leak detection.

Test Procedure

Test 1.—This test was to some extent a repeat of the initial proving test of the reactor pressure vessel. On the earlier test the vessel had been fully strain-gauged in order to determine the general stress levels and also to investigate in greater detail the stresses in those regions where stress concentrations might be expected; the maximum pressure attained was 135 lb per square inch gauge. Between the two tests the reactor had been loaded with some 1200 tons of graphite, the sampling plant pipework had been installed, the charge tubes had been fitted and separately air tested, and the control mechanisms had been installed. In total some 1400 to 1500 tons of equipment had been put into or onto the vessel, and it was to the support system, therefore, that attention was directed.

Three pairs of internal and external support brackets, corresponding to three of the ten inverted " A " frames, and the shell in their vicinity were strain gauged, internal leads being passed through a " gooseneck " connection and sealed. Only increments of stress were obtained since the actual stresses at the start of the test were indeterminate. This arose from the fact that zero drift was known to take place with time on strain gauges and some twelve months elapsed between the two tests. New gauges were, therefore, fitted for the second test.

The vessel was pressurised to 115 lb per square inch gauge (the safety valve setting), in stages. No yielding was observed on the gauges and the increments of stress were almost identical to those observed during the unloaded test.

All seal welds, glands, gasketted joints and, where possible, the gas tightness at the seating of valves were observed. Faulty seal welds were repaired on reactor blow down, glands were tightened under pressure and, if necessary, repacked on blow down. Valves were " cracked " to remove any dirt from the faces, or the seats reground on blow down if sealing was not satisfactory. Repeated pressurisation was necessary on certain of the tests until gas tightness was achieved on seal welds or leakage was reduced to an acceptable figure in the case of glands.

A functional test at full pressure was carried out on the control rods, their operating mechanisms and their associated electrical gear and instrumentation.

Clearances between all pressure vessel branches and the biological and thermal shields were checked, as also were the indicators on the constant load duct support hangers, both before and after test.

Test 2.—The 18in valves connecting the auxiliary circuit to one of the main 54in outlet and corresponding inlet ducts, inboard of the 54in valves, were opened and one of the air compressors run to make up the air lost from the labyrinth type gland on the auxiliary circulator. Leakage tests were carried out as in Test 1. On completion of the test the 18in valves were reclosed and spade plates fitted to avoid continued leakage at the labyrinth gland.

Test 3.—The complete main system was pressurised to 100 lb per square inch gauge only, this being the maximum that could be accepted by the bellows units to which cold draw had been applied, in order not to exceed the design maximum stress. During the later hot test this restriction did not apply, since thermal expansion of the system had relieved the cold draw.

Leakage tests were generally as before; particular attention was paid to the joints on the circulator casings and to ancillary circuit isolating valves.

Test 4.—The ancillary circuits were pressurised and tested one by one by opening one of the isolating valves off the main circuit. In the previous tests care was taken to leave all ancillary circuits vented to atmosphere in order not only to check for leakage at the isolating valves, but also to safeguard the test team in the event of mal-operation of valves or equipment outboard of the isolating valves.

Test 5.—The system having been proved pressure tight, with the exception of manholes left for entry to the reactor pressure vessel and heat exchangers and for temporary telephone and lighting cables, the dynamic tests were started after jacking off the circulator stationary seals.

Stage 1.—Eight full-flow cotton filters in the form of socks were fitted, one in each of the four inlet ducts and four outlet ducts. The former prevented the reactor receiving contamination from the external circuits and the latter the converse. The high standard of cleanliness achieved throughout construction was fully demonstrated in that the filters in no case collected more than an eggcupful of material. This consisted of lint (presumably off clothing), wood chippings (off scaffolding boards and screens), and a small quantity of iron oxide; in addition, the top filters contained some graphite dust. A small quantity of material was also deposited, on shut down, in the inlet manifold to the reactor vessel and on the charge pans, from the relatively low velocity regions at each end of the reactor core. On shut down of the circulators the filters and deposited material were removed.

The steam supply to the water side of the heat exchangers which were hot stored was switched off two days before this test in order to achieve comfortable working con-

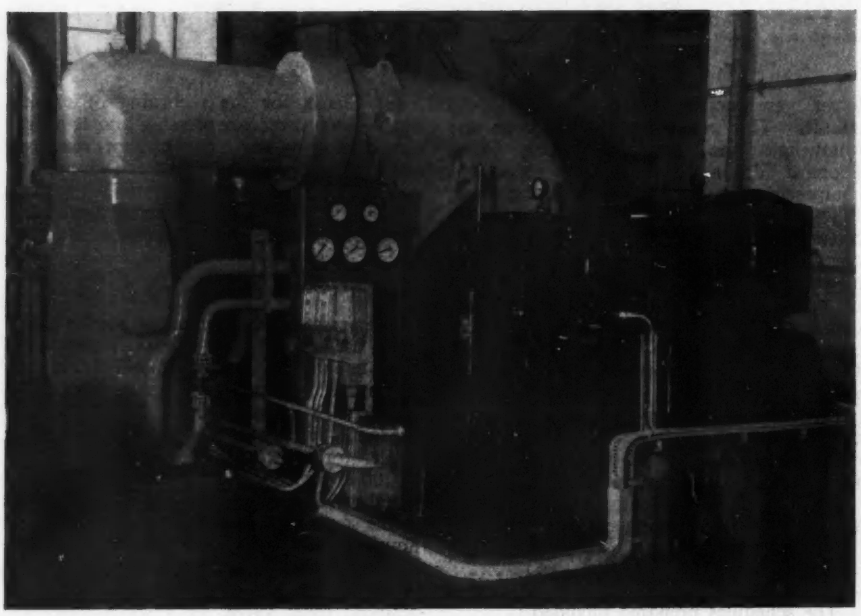

Fig. 4—Auxiliary circulator

ditions within the circuit. To prevent internal condensation, the temperature was not allowed to fall below 24 deg. Cent. (75 deg. Fah.).

Stage 2.—Even greater care was taken in the planning of this test than elsewhere to guarantee against the possibility of accident. Staff were placed in pairs within the circuit to check the behaviour of the installation, with particular reference to fairings, pipes and fittings at full gas velocity. The density was well down on that obtained in service, but this was the maximum that could be achieved with staff inside the circuit. They were positioned in the base of the reactor vessel behind the conical fairings, access being through a 2ft by 2ft manhole in the fairing, in the top of the reactor vessel and in one of the heat exchangers. Lighting was installed to enable a thorough inspection to be made and each pair had direct telephone communication with the main control room. The staff were provided with helmets, masks, goggles and wooden mallets, these last in order to communicate by pre-arranged tapping signal to a colleague outside the system, in case of telephonic failure or if the noise level got too high. Safety grills were also fitted across the outlet ducts from the reactor to guard against the staff being swept into the outlet nozzles where the velocity at full circulator speed would be approximately 75 m.p.h.

The test which lasted two hours went off without any hitch. The speed was increased in stages until trip took place on circulator overspeed at 1040 r.p.m. Speed increase was only made with consent from all those within the circuit. The staff were obviously strained by the high noise level, but they were pleased with the behaviour of equipment and no faults were reported. A noticeable feature on the ungagged and uncharged reactor core was the much higher velocity in the centre channels than the peripheral channels, due to the nozzle effect from the 12ft diameter inlet manifold.

Throughout the test, the behaviour of the circulators, their driving motors and ancillaries and the running seal were observed. On completion a thorough examination of the complete circuit was made.

TEST 6.—The fuel element charge and discharge machines, Fig. 6, and the charge chutes were operationally tested at various positions over the charge face of the reactor. The action of the chutes was observed from within the vessel as they were made to operate in turn on the three radii covering the sixteen channels served by one charge tube. A separate test facility is fitted on the discharge face of the reactor to assist in the training of operators for this procedure.

TEST 7.—This was a combination of Tests 3 and 5. The circulators were satisfactorily operated throughout the speed range 0 to 940 r.p.m., and the complete circuit was checked for vibration. It was found that certain of the charge tubes were vibrating and in a later separate series of tests it was proved that these tubes were those towards the centre of the reactor, to which control mechanisms were not fitted, and which were to be used for neutron flux measurements within the core. The vibration was "eliminated" by fitting the actual flux winding heads, each weighing some 250 lb.

Flows were compared between the circulator inlets, which had been calibrated on the circulator works test to determine the characteristic, and the reactor outlet venturis.

TEST 8.—This was probably the most important test of the series since the whole of the bottom duct system to and from the circulators, the support of the reactor vessel and the heat exchangers and much of the ancillary plant was operating at its design condition. It is the maximum temperature at which the top duct system can be operated without heat input at the reactor which at this stage is not loaded. The test was carried out in three phases as follows :—

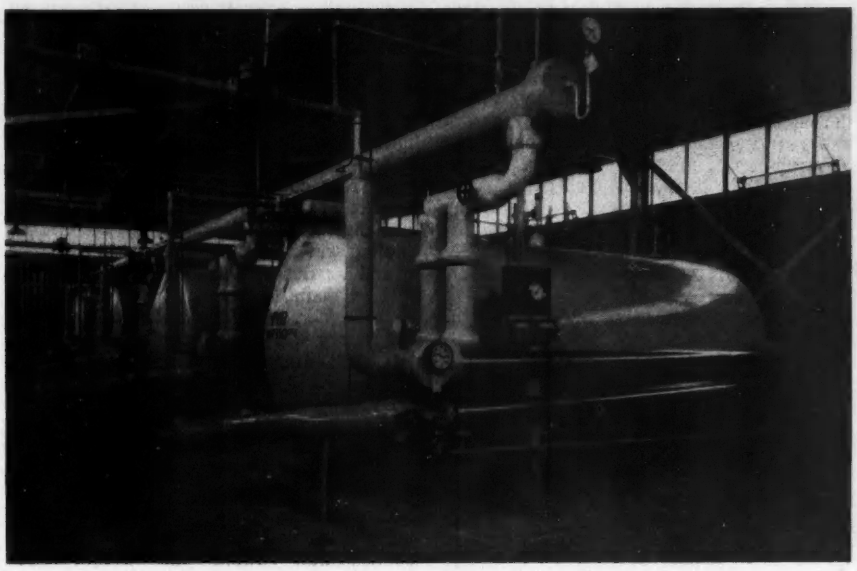

Fig. 5—CO_2 storage plant and evaporators

Heating Phase.—Heat input to the system to raise the temperature was achieved in two ways—by the heat corresponding to the power input at the circulators, and by actual steam injection into the l.p. and h.p. drums on the heat exchangers with circulating pumps running. The latter accounted for by far the greater amount. The steam (some 16,000 lb per hour maximum at 80 lb to 100 lb per square inch gauge) was obtained from the boiler plant on the adjacent Windscale factory. The temperature was raised to 140 deg. Cent. (284 deg. Fah.) in approximately forty-three hours. Care was taken throughout the test to avoid large temperature differentials within the system and thermocouples were fitted to check this point. The reactor vessel was strain gauged both internally and externally in the region of the support brackets, using similar instrumentation to that used for Test 1. In addition, clock gauges were fitted from fixed brackets to determine the movements of the supporting brackets and inverted "A" frames. The strain gauging was undertaken in order to study the incremental stress distribution arising from the combination of the thermal expansion of the vessel and pressure. It was considered advisable to raise the temperature of the circuit to 140 deg. Cent. (284 deg. Fah.) at atmospheric pressure and then to increase the pressure in stages to 115 lb per square inch gauge in order to obtain greater reliability in the strain-gauge readings. Once again there was no indication of yield and the incremental stresses were almost identical to those obtained previously.

The duct constant support hanger readings were recorded at intervals throughout the test, and extrapolation to the final temperature condition made in the case of the top ducts in order to check the upper limit of movement, Fig. 7.

All clearances between the shielding and charge tubes, main ducts and other branches

Fig. 6—Pile cap showing charge and discharge machines, control mechanisms and flux plotting winding heads

passing through the biological shield were checked and extrapolated to full temperature conditions in a generally similar manner.

Steady Conditions Phase.—The steam supply was shut off and the heat input from the circulators dissipated partly by general losses from the system, and partly by allowing the l.p. boilers to steam at a pressure of about 18 lb per square inch gauge. The steam produced was passed to the dump condenser where it was transferred to the cooling water system and finally rejected at the cooling tower. The outlet temperature was held steady by control of the steam pressure. Make-up water was injected into the

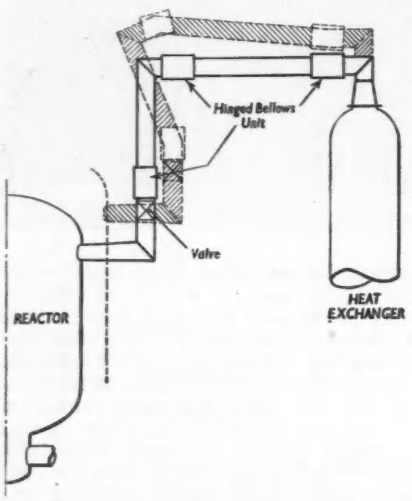

Fig. 7—Diagram showing how expansion of the duct system is catered for by deflection at the bellows units

drums with care to avoid violent temperature changes.

During this phase, the complete system was re-checked for leakage. Circulator performance was observed, with particular reference to the temperatures of bearings, running seal and cooling air, the commutation and other electrical measurements. Run down times to pickup on the d.c. pony motors (normally supplied with rectified a.c. and backed up by battery and diesel generator) and to standstill with the pony motors cut out were recorded. Trip-in of the diesel generators was checked on a.c. failure. The auxiliary circulator and circuit were checked with the main circulators at standstill.

The ancillary circuits (driers, filters, cyclones &c.) were brought on line and operationally checked and their performance recorded. Mass flows were measured from the installed orifice plates.

The sampling plant was operationally checked and the performance of the associated main and auxiliary carbon ring compressors observed. The control gear was operated throughout the speed range and on emergency trip.

Instrumentation and all trip circuits and alarms were checked. Safety valves were lifted and the settings checked by gas bottle connected to the space between isolating valve and safety valve.

Cooling Down Phase.—At the conclusion of the trials the circuit was cooled down in order to allow personnel to enter and inspect the circuit.

The humidity of the air within the circuit was checked to ensure that condensation would not result, on temperature reduction. This humidity arises from the release of water from the graphite moderator. Blow-down and re-charge with dry air was not necessary, but might prove necessary on future reactor tests.

Cooling was obtained initially by allowing the l.p. boilers to blow off steam to atmosphere and later by the feed water coolers. These coolers are a part of the installed system to reduce the reactor temperature in case of complete shut down. They are situated in the feed water system to the heat exchangers and are cooled by the normal cooling water system. The circulator speed was also reduced to lower the heat input, yet still to maintain circulation with adequate heat transfer. As the temperature decreased the reactor was blown down.

TEST 9.—Immediately following blow down the complete circuit was subjected to a vacuum test using the installed rotary exhauster. In the earlier tests on the reactor pressure vessel a vacuum of 27·5in Hg. had been achieved. The aim in the present test was 27in Hg.

Care was again taken to prevent moisture being driven off the graphite with possible condensation within the circuit. The graphite temperature in the previous test was therefore reduced below 46 deg. Cent. (115 deg. Fah.), the boiling point of water at the above vacuum.

Dry air was charged into the system on completion of the test, which concluded the test work on the reactor. A thorough inspection was then made of the complete plant.

TEST 10.—The CO_2 plant was charged with carbon dioxide, delivered in road tankers, and the plant up to the actual delivery valves at the reactor tested. The tests included checks on the refrigeration plant, the evaporation rate with blow-off to atmosphere, safety valve settings, and operation of reducing valves.

TEST 11.—The purpose of the test on the shield air cooling system was to adjust the inlet and outlet dampers to each of the four main passes cooling the bottom shields, vertical shields, roof shields and that cooling the charge tubes and reactor spaces. This adjustment was necessary to attain the design air flows in each pass, and at the same time achieve "pressure" balance between the passes to keep cross leakage to a minimum. Pressure tappings from the various passes were brought up on to a manometer board at pile cap, and this was observed during the actual adjustment of the dampers.

The four centrifugal fans (two run, two standby), each with a.c. driving motor and their emergency vee belt drive from d.c. motor, had been checked and mechanically proved on completion of erection.

This completed the commissioning trials and, following the loading of the fuel element support struts, the plant was handed over to the Operations Branch on May 17th.

Acknowledgment is made of the work done by Mr. R. Davies, who has checked the manuscript of this article and who was responsible for the preparation of the schedules which formed the basis of the tests described.

(To be continued)

Place of Calder Hall Reactor in Nuclear Power Generation

By SIR CHRISTOPHER HINTON, M.A., M.I.C.E., M.I.Mech.E., M.I.Chem.E., F.R.S.*

A symposium on Calder Works nuclear power plant is being held by the British Nuclear Energy Conference this week at the Institution of Civil Engineers and the Central Hall, Westminster. In a lecture given at the opening meeting yesterday, Sir Christopher Hinton sought to put the graphite-moderated gas-cooled reactor into its correct perspective in the atomic energy field. Abstracts from the lecture are reproduced here. The symposium† ends to-day.

DESIGN and construction of the Windscale plutonium producer was completed in 1950 and careful consideration was given to the question of whether the team which had been engaged on this should proceed with the development of the graphite-moderated gas-cooled power producer or whether it should be employed on the design and development of a fast reactor. At that time there was some uncertainty about the breadth of the development programme for which finance would be available and it was thought that the general technology of reactor design could be carried further by deploying the available team on the development of the fast reactor rather than by allocating it to the reconsideration of the graphite-moderated gas-cooled system.

I think it is fair to say that Tongue, who was Chief Engineer at Harwell, was never very happy about this decision. His engineers had continued the earlier work which had been done by Risley and in the light of the additional knowledge which was available this work showed increasing promise. He therefore pressed to be allowed to continue and to expand this work, which was done by Goodlet and Moore in collaboration with Babcock and Wilcox, Ltd., Parolle and Head Wrightson and Co., Ltd. In working on this study they were able to take advantage of experience that had already been gained in the operation of the Windscale piles and also of recent development work done under the control of the Ministry of Works in the design and construction of the very large pressure vessels required for the wind tunnel at Bedford. The design was also made less cumbersome by the adoption of stud tube boilers. The study produced a preliminary scheme for a nuclear power plant which, when optimised for the generation of electricity with the production of plutonium as a by-product, appeared to offer an efficiency of about 25 per cent.

At about the time when these investigations were completed the Atomic Energy Organisation received a demand for additional plutonium for defence purposes and it was felt that this could be met most economically by building reactors of the general type evolved in the feasibility study but optimised for plutonium production. The project was approved in March, 1953; a site separated from the Windscale Works only by the River Calder had been acquired and approved for factory construction some

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† The proceedings of the symposium are to be printed in the *Journal of the British Nuclear Energy Conference*, in the issues of April and July, 1957.

years previously and work began on this site during summer of 1953.

It is important to realise that, like many plants in the process industry, a power-producing reactor using natural uranium as fuel gives two products, namely, electrical energy and plutonium. Either of these two can be regarded as the primary product, in which case the other is the by-product. In the Calder Hall piles the primary product is plutonium for defence purposes, electrical energy the by-product. If the plutonium were to be valued at the cost at which it is produced from reactors of the Windscale type, the cost of power produced in the Calder Hall piles as a by-product would be very low. Such a costing system obviously will not be used and the plutonium will be produced at a considerably reduced price by crediting the plant at a reasonable rate with

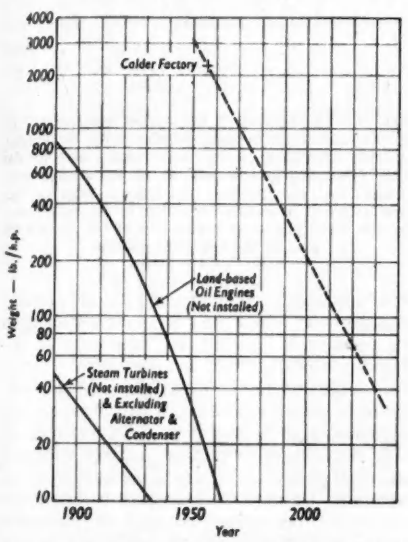


Fig. 1—Comparison of weights of steam turbines, land-based oil engines and Calder factory

the electrical power. It cannot be emphasised too strongly that from the industrial point of view it would be misleading to talk about the cost of electrical power produced in the reactors at Calder Hall ; the industrial cost of power from reactors of this type can be determined only from designs for reactors which are optimised for the production of electrical power and which produce plutonium as a by-product.

The differences in design required by a re-optimisation for power production purposes are, however, quite minor and by the end of 1953 we were satisfied that reactors of this type could be used as a basis for a major development of nuclear power in Great Britain. A scheme for doing this was prepared by Kay, Geoghegan and Poulter, who set out a long-term plan to this end. In this they envisaged the initial construction of a series of reactors of the Calder Hall type and calculated that such reactors should be able to produce electrical power at a cost of about 1d. a unit. It was realised, moreover, that the plutonium produced as a by-product in these reactors could be used as a fuel in other reactors. Their report pointed out that in all probability this by-product plutonium could not be used satisfactorily in gas-cooled reactors and that it would be necessary to develop liquid-cooled reactors of higher rating to burn it satisfactorily.

The Kay, Geoghegan and Poulter Report was used as the basis of an interdepartmental study, and with some developments and modifications it formed the basis of the White Paper which was published in February, 1955.

Thus the Calder Hall type of pile has the distinction of forming the basis of the world's first comprehensive long-term programme for the development of nuclear power and it is essential that we should be quite clear why it occupies a position of such distinction.

The art of the engineer is, and always has been, to make use of available scientific knowledge, materials and techniques to produce plants which are sufficiently economical and reliable to be used with confidence in industry. He must be quite firm in setting on one side scientific theories, however attractive, if he has not got at his disposal the materials and techniques which enable him safely and reliably to translate these theories into industrial practice. This is what James Watt did when he designed his early steam engines ; he was certainly conscious of the fact that far higher efficiencies were achievable theoretically, but he firmly used the best and most reliable design which could be attained with the materials and techniques which were at his disposal when he was installing his engines.

In designing the Calder Hall reactors we have been in a similar position and have produced a similar result. The Calder Hall piles are heavy, cumbersome and expensive in capital cost per kilowatt, but they are inherently safe, they use natural uranium as a fuel and their construction makes use of materials which have been in routine production for a considerable time and of techniques which are either well established in themselves or are normal developments of established techniques.

The figures given in the White Paper show that reactors of the Calder Hall type can produce power at a cost comparable with that of a modern station using conventional fuel.

In engineering plant which has to be sold to industrial operators these are solid and vital advantages, and at to-day's date the Calder Hall type of reactor is the only nuclear power plant for which these claims can be made.

History tells us, however, that the weight per horsepower and capital costs (in terms of real money per horsepower) fall with the passage of time for all types of prime mover. This is indicated in the graphs shown in Figs. 1 and 2. Fig. 1 plots against time the weight per horsepower of land-based oil engines and of steam turbines and shows the progressive decrease in weight per horsepower which accompanies the development of better materials of construction and better techniques of design. On this graph is shown a curve which assumes the same general characteristic for the weight per horsepower of land-based nuclear power plants, and a study of this curve is interesting because it gives some indication of the date at which the weight per horsepower of economical nuclear plants can be expected to fall to levels at which such plants may be installed economically on moving platforms.

The second chart gives the cost per horsepower of steam prime movers and of land-based oil engines and again gives an imputed curve for the capital cost of nuclear power plants. From the White Paper it is possible to deduce a capital cost per kilowatt of £125 for the earlier power stations of the Calder Hall type and this is used as the starting point for the curve on Fig. 2.

It must, of course, be recognised that the curves in Fig. 2 are not strictly comparable, because the cost for the nuclear power plant includes the civil engineering work ; this has been done because much of the civil work (such as the biological shield) is an integral part of the plant and cannot be separated from other civil engineering work on the station. Although the curves are not strictly comparable, Fig. 2 is useful in showing trends. It sets out clearly the fact that past experience has indicated that costs of prime movers have come down rapidly and steadily as time has passed.

There is no reason to anticipate any different pattern with nuclear power stations. As experience grows and as better techniques and better materials are developed higher initial temperatures in the heat cycle will be achieved, giving greater outputs and higher thermal efficiencies ; higher gas pressures in the cooling system will be used, giving lower gas circulating costs ; better heat exchanger

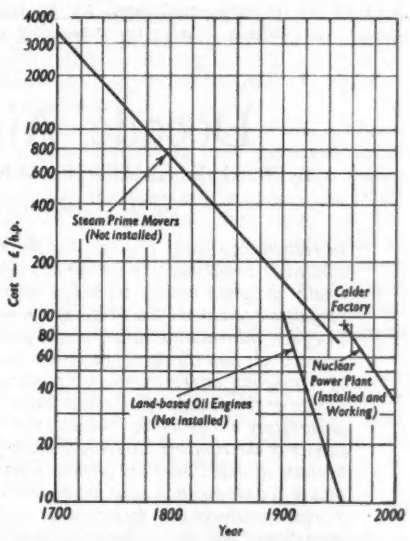


Fig. 2—Comparison of 1954 equivalent capital cost of steam prime movers, land-based oil engines and Calder factory

surfaces will be developed and greater specific ratings thereby will be achieved. All these and other improvements will lead to the reductions in capital cost which are predicted in Fig. 2. The immediate importance of such capital cost reductions must be appreciated in the light of the fact that, whereas in a conventional power plant roughly three-quarters of the cost per unit of electricity sent out represents fuel and operating costs and only one-quarter is accounted for by capital charges, in nuclear power plants a far higher proportion of the cost per unit sent out arises from the capital charges : indeed, this proportion is more nearly two-thirds of the costs. The effect of reduced capital charges on the cost per unit is therefore important.

Reduction in capital cost in accordance with the hypothetical curve imputed and shown on Fig. 2 would give in 1975 a cost per unit of 0·5d., and this takes no account of reduction in cost of the ancillary processes (such as chemical extraction) which might also be expected.

In my view, the merits of the Calder Hall type of reactor and the potential improvements which can be made in its design are such that plants of this type will still be built twenty-five years from now. In the second half of that twenty-five-year period, however, it will be replaced in certain land-based applications by reactors of higher rating and in the very long term it will, for most purposes, be superseded by such reactors. Reduction in weight per horsepower beyond a certain

point will not be possible with the use of gaseous coolants ; to get further we must achieve the higher ratings which can only be achieved by the use of liquid coolants. The use of these liquid coolants at present is not industrially practicable because either they involve technological problems which have not been solved or they demand materials which are not in commercial supply, or they call for the use of enriched fuel. In time these problems will be overcome, and as this is done highly rated reactors using liquid cooling will be employed ; first, in those special applications where the user can afford to pay inflated prices for reduced weight per horsepower, and then, as the cost of the special materials demanded falls with increasing experience of their production, for normal industrial applications.

It follows, therefore, that while putting all necessary effort into the further development of the graphite-moderated gas-cooled reactor to obtain what is immediately practicable we must press forward to the development of those other systems which are not at present industrially attractive.

It was the development of the low-speed reciprocating engine by James Watt, and its later refinement by other great engineers, which laid the foundations of Britain's lead in the industrial revolution of the nineteenth century ; but it was the subsequent invention of the reaction turbine by Parsons and the development of the internal combustion engine by men like Dugald Clerk which enabled Britain to retain that lead. The Calder Hall reactor is giving us the initial lead in the use of nuclear power and we shall be able to retain that advantage for at least a decade by improvements in this type of reactor. But we shall maintain that leadership in the long term only by development of reactors which are capable of higher ratings. It is in that direction that the development work of the United Kingdom Energy Authority is turned at the moment.

Decade Air Condenser

By W. H. F. GRIFFITHS, M.B.E., F.Inst.P., M.I.E.E., S.M.I.R.E.

No. II—(*Concluded from page 693, November 16*)

In response to many requests for the simplification of the scaling of variable air condenser standards, the author has devoted much thought to the problem and has finally designed and developed a decade air condenser which may be used with confidence to extend the range of a variable air condenser by one or two decades. In effect, this solution simplifies the problem of scaling by ten or one hundred times respectively and eliminates most sources of scale reading inaccuracy as well as those of erroneous interpretation of reading. This article is devoted entirely to the design of the decade of air capacitance and the virtual elimination of all sources of uncertainty of capacitance which might occur. The conventional variable air condenser of the rotating interleaved plane plate type is used as the basis of design and, because of this, ill-defined angular settings of one plate system relative to the other at any decade position must not be allowed to affect the capacitance at that position. Various methods are described of ensuring capacitance stability despite angular uncertainty and the various stages of improvement from the simple variable air condenser are given quantitatively by means of curves of C *and* dC/dθ.

LOW as these values of $dC/d\theta$ are in comparison with those which would be obtained in an ordinary variable condenser (in which the value would be about 6·7 throughout the range), the author felt that they should be still further reduced. This reduction was effected by the introduction of a negative $dC/d\theta$ to compensate the residual positive value throughout a small angular displacement on either side of every decade setting. The method employed is shown in the drawing of Fig. 10, in which it is seen that a number of radial slots, each shaped and positioned carefully, are punched in the fixed plates. Each slot is positioned angularly with care so that the leading radial edge of the *first* moving plate sector just appears (by a degree of arc) at every decade setting in which such compensation is found to be necessary. In Fig. 10, the moving plates are to be seen set to the first or 100$\mu\mu F$ position of the decade and so the leading edge of the *first* sector just appears in the 100$\mu\mu F$ slot by 1 deg.

Having established, experimentally, that such a method of compensation introduces a $dC/d\theta$ value of −0·25 per slot,† it is easy to arrange the number of fixed plates to be slotted for each decade position up to position 4. Thus, referring to Fig. 10 and to the tabulation of $dC/d\theta$ values, it is seen that the number of fixed plates to be slotted are as follows : 100$\mu\mu F$ setting, 2 plates to be slotted ; 200$\mu\mu F$ setting, 3 plates to be slotted ; 300$\mu\mu F$ setting, 4 plates to be slotted ; 400$\mu\mu F$ setting, 5 plates to be slotted, the number of slots effective at any decade setting being proportional to the residual value of $dC_R/d\theta$ at that setting.

So far, the compensation has proceeded without complication, but now, at the 500$\mu\mu F$ setting shown in Fig. 11, it is seen that the residual positive value of $dC_R/d\theta$ is augmented by positive values of $dC/d\theta$ due to the moving plate sectors 2 and 3 which, with positive angular rotation, are disappearing from the 200$\mu\mu F$ and 300$\mu\mu F$ slots respectively and are thus increasing the total amount of interleaved plate area. From the tabulation of residual values of $dC_R/d\theta$ it is seen that decade position 5 should require only five slots for exact compensation to which number must now be added a further seven slots to provide compensation for the seven slots of positions 200 and 300, making twelve slots in all.

By experiment, the author found that the number of slots necessary on any given decade position was not always exactly as expected and in this case, for example, fifteen plates were slotted before the value of $dC/d\theta$ could be reduced to zero.

Positions 600 and 700 of the decade were also complicated by the compensation of the previous decade positions and were given 12 and 15 slots respectively.

In positions 800, 900 and 1000 it was found impossible to reduce the value of $dC/d\theta$ to a sufficiently low value by this method of slotting. In fact, at these positions there already existed very appreciable negative values of $dC/d\theta$—due to incidental overcompensation in the cases of the 800 and 900 positions and to the approaching ultimate proximity of the radial edges *A* and *B* of the fixed and moving plates, as shown in Fig. 12, in the case of the 1000$\mu\mu F$ position. In such cases since the sign of $dC/d\theta$ between the decade positions must always be positive,

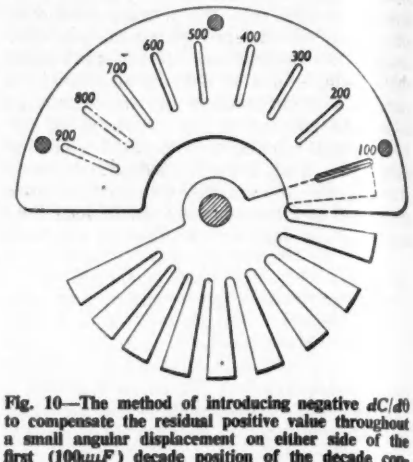


Fig. 10—The method of introducing negative $dC/d\theta$ to compensate the residual positive value throughout a small angular displacement on either side of the first (100$\mu\mu F$) decade position of the decade condenser. At this position the leading edge of the first sector is seen just appearing in the radial slot of the fixed plate—to reduce the active interleaved area of the two plate systems

it is obvious that there must be an angular position θ at which the sign of $dC/d\theta$ changes to positive. The angular positions of the last three positions of the decade are, therefore, adjusted to the exact point of a maximum or minimum value of $dC/d\theta$ where the algebraic sign is changing. An example of this method of obtaining a zero value of $dC/d\theta$ is given in Fig. 16 of the curves which will now be used as examples to show the degree of perfection attained in the compensation of the decade air condenser already described.

In all decade arrangements the first position must always receive the most care, since not only is it the most difficult to adjust and stabilise to any given accuracy on account of its low value, but also it has no prior positions to act as possible dilutions of its errors or instabilities. The first position of a decade, so to speak, has to bear the full burden of its own short-comings and because of this the first or 100$\mu\mu F$ position of the decade air condenser must be treated exceptionally.

The curves of Fig. 13 show the success which attended the author's efforts to com-

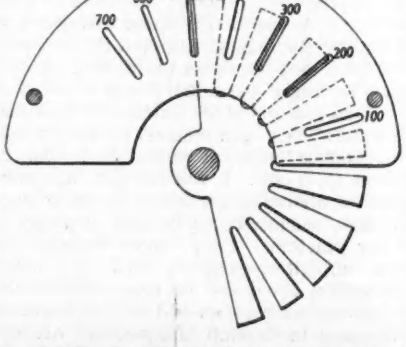


Fig. 11—The complication of the compensation of residual $dC/d\theta$ in the fifth (500$\mu\mu F$) decade position of the condenser. With positive angular rotation of the moving plate system the increases in active area evident at slots 200 and 300 make necessary still further compensation at the 500$\mu\mu F$ slots

† This value of $dC/d\theta$ holds for a very small angular displacement on either side of the decade setting, it being unnecessary to consider angular uncertainties greater than, say, ±1 deg. or to provide compensation outside this region.

pensate the small residual $dC/d\theta$ at the first or 100$\mu\mu F$ setting of the condenser. The curves show the change of capacitance with angular displacement of the moving plates on either side of zero angle—the angular position of the click for this first decade position. In these curves, as in those which follow, a positive angular displacement from zero angle indicates rotation of the moving plate system towards the next higher decade position. The straight line reference curve is that of the linear capacitance change which would be obtained in an ordinary variable condenser of comparable capacitance range—having a $dC/d\theta$ value of 6·7. The $dC/d\theta$ value of the decade condenser midway between adjacent decade positions is somewhat greater than this—of necessity so because of the angular wastage between the fingers of the moving plates. The actual value in this condenser is about 9.

The continuous curve shows the effectiveness of the general principle of the uncompensated decade air condenser in which, for small angular uncertainties of the order of 1 deg., it will be seen that the value of $dC/d\theta$ has been reduced from +6·7 to +0·4. This extremely small value the author has still further reduced (sensibly to zero) by compensation as the broken line curve shows. The inset curve is an enlargement to show more clearly what happens when the angular uncertainties are limited to those likely to be experienced in practice. It is seen that there is absolutely no measurable change of capacitance for angular uncertainties of the order ±12 minutes of arc or even more.

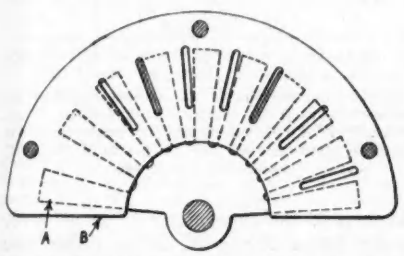


Fig. 12—Showing the incidental over-compensation of the tenth (1000$\mu\mu F$) decade position. The over-compensation is caused partly by the compensation of the previous positions of the decade and partly by the proximity of the radial edges *A* and *B* of the moving and fixed plates respectively

In Fig. 14, similar curves are given for the third position of the decade. These curves are perhaps more informative because of the more limited angle through which the whole change of "slope" occurs. Again, they show the perfection of the compensation of the residual $dC/d\theta$; it has been reduced from a value of +0·8 to sensibly zero. The effective value of $dC/d\theta$ over ±12 minutes of arc is of the order +0·03, which means that sensibly no change of capacitance can be detected within this angular uncertainty.

As an example of compensation at a more advanced position of the decade, the fifth or 500$\mu\mu F$ position is shown in Fig. 15. Here, again, the continuous line curve gives the normal reduction in the value of $dC/d\theta$ in the angular vicinity of the "click" and the broken line curve the ultimate compensation obtained. It will be seen that the compensation in this case is hardly without complication, for it has introduced a suspicion of change of sign of $dC/d\theta$ in the neighbourhood of +1 deg. This is slight, however, and the compensation in effect reduces the value of $dC/d\theta$ from 1·1 to zero. From the enlarged curve it will be seen that the effective value of $dC/d\theta$ over ±12 minutes is only of the order −0·05, resulting in a sensibly constant capacitance throughout this angle.

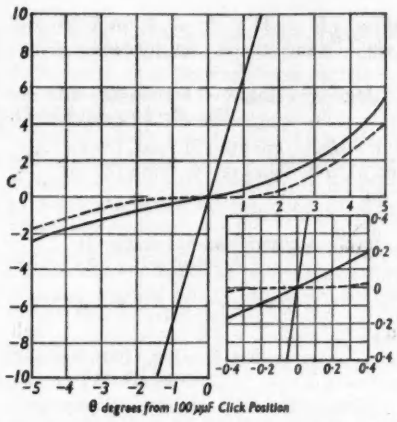


Fig. 13—Curves depicting the virtual elimination of $dC/d\theta$ in the proximity of the first (100$\mu\mu F$) decade position of the decade condenser. The full line curve shows the residual capacitance slope at this position and the broken line curve the further improvement effected by compensating this residual. The small inset curves merely show more clearly what happens within the extreme angular excursions (from the click positioned angle θ) which could possibly be occasioned by geometrical uncertainties in the click mechanism. The steeply sloped straight line curve shows, for comparison, the capacitance slope of an ordinary variable condenser of comparable value

The ninth position of the decade is a good example of over-compensation as the curves of Fig. 16 show well. Here, throughout an angle of about 4 deg., the residual $dC/d\theta$ is over-compensated to become very appreciably negative and it is only by adjusting the angular position of the click to the "maximum" of the compensation curve that the value of $dC/d\theta$ can be reduced to zero. This method is very successful as the enlarged curve shows. The actual value of $dC/d\theta$ at $\theta=0$ is, of course, zero, but the effective value over an angular displacement of ±12 minutes is −0·35, which means that angular uncertainties of this order will produce corresponding uncertainties of capacitance always less than −0·01 per cent.

From the above four examples of methods of reducing the values of $dC/d\theta$ at the various decade positions it is seen that a very great measure of success attended the author's attempt at complete compensation of residual capacitance "slope." This success is, perhaps, shown more clearly by plotting curves of $dC/d\theta$ around a click position before and after the residual had been compensated. In Fig. 17 such curves are shown for the third (300$\mu\mu F$) decade position, the full line and broken line curves being plotted for the uncompensated and compensated cases respectively. From this curve it will be seen that the minima occur at slightly different angular positions, but this is of no consequence since it is known beforehand which of the two cases the click cutting has to suit.

The tabulation below summarises the successive stages of improvement in the four decade positions shown by the curves of Figs. 13 to 16.

From this summary it is seen that the author's compensated decade air condenser is at least 100 times less dependent upon exact angular setting at all capacitance values than would be an ordinary variable air condenser.

In assessing the efficacy of the author's methods, however, it must be remembered that the angular certainty of the zero setting must also be taken into account. As in all decade arrangements the value of the capacitance at any given decade position is really the difference between that capacitance and the (false) zero value. In the present design, therefore, it is seen that the value of $dC/d\theta$ at the zero decade position is of great importance.

At least it should be appreciably less than the effective value of $dC/d\theta$ at the first decade position which should, in turn, be lower than that of any other position of the decade if a roughly uniform percentage accuracy is expected.

Improvement in Four Decade Positions Shown by Figs. 13 to 16

Capacitance setting, $\mu\mu F$	$dC/d\theta$ at click positions				$\Delta C/\Delta\theta$ over ±12′	$\Delta C/C$ for ±12′
	Ordinary variable condenser	Residual of decade air condenser (calculated)	Residual of decade air condenser (measured)	After compensation		
100	+6·7	+0·4	+0·4	0	0	0
300	+6·7	+1·0	+0·8	0	+0·03	0
500	+6·7	+1·6	+1·1	0	±0·05	0
900	+6·7	+3·0	+2·5	0	±0·35	$<\pm10^{-4}$

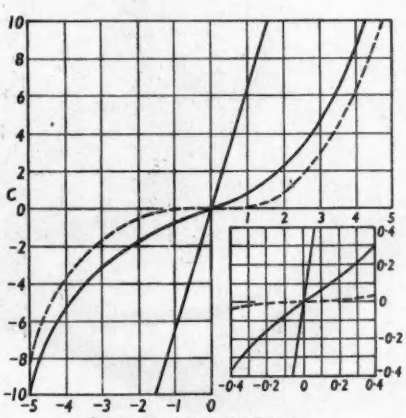


Fig. 14—Curves showing the virtual elimination of $dC/d\theta$ in the proximity of the third (300$\mu\mu F$) position of the decade air condenser. The line code is that described in the caption to Fig. 13

The best position of the moving plate system for the zero of the decade is obviously one of symmetry with the fixed plate system, so that the angle between the leading radial edges *l* of the moving plates and the radial edges of the fixed plates into which they are entering is equal to that between the trailing edges *t* and the fixed plate edges which they are leaving.

Because of this symmetry it will be seen that the capacitance at $\theta=0$ will be a minimum and $dC/d\theta$ will therefore be zero at this point. This must not be interpreted necessarily as an indication of stability of zero capacitance for a given angular uncertainty; the only true criterion of this condition is the value of $d^2C/d\theta^2$, and this, it will be seen, may be very high even at $\theta=0$.

It is necessary, therefore, to be able to assess the value of $d^2C/d\theta^2$.

Let the space angle between the radial edges of the fixed plates and the leading radial edges *l* of the moving plates be α.

Then if ψ is the angular extent of the moving plates and ϕ that of the fixed plates,

$$\alpha=k-\theta,$$

where

$$k=\tfrac{1}{2}\{2\pi-(\psi+\phi)\}$$

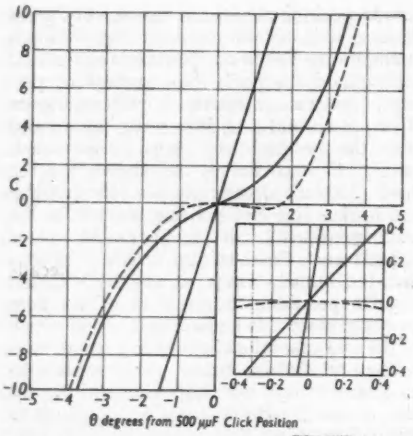


Fig. 15—The elimination of $dC/d\theta$ at the fifth (500$\mu\mu F$) position of the decade air condenser. In the broken line curve over-compensation is a little in evidence, producing a negative slope so slight, however, that it may be ignored at the very flat maximum value of C where $dC/d\theta$ is virtually zero for the considerable angular excursions shown in the magnified inset curve

and the corresponding angle associated with the trailing edges t is $\theta+k$.

Then from (3) the leading edge capacitance $C_{E(l)}$ between the l edges of the moving plates and the fixed plates

$$C_{E(l)}=\frac{M}{7\cdot2\pi}(\log_e R_m-\log_e r)\cot\tfrac{1}{2}(k-\theta)\mu\mu F,$$

and for the trailing edge capacitance the edge angle is $\theta+k$ and so

$$C_{E(t)}=\frac{M}{7\cdot2\pi}(\log_e R_m-\log_e r)\cot\tfrac{1}{2}(\theta+k).$$

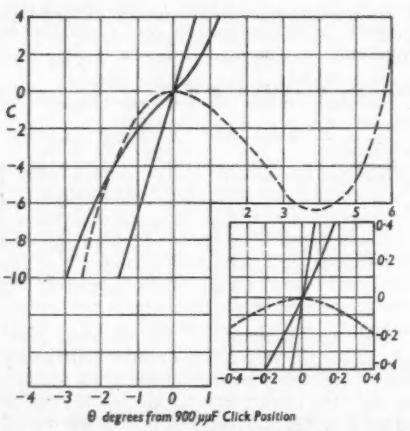


Fig. 16—The special treatment required to reduce the value of $dC/d\theta$ at the ninth (900$\mu\mu F$) position of the decade air condenser. In this case the considerable residual $dC/d\theta$ shown by the full line curve is incidentally over-compensated by the compensation of the earlier positions of the decade to produce the negative slope in the broken line curve. Fortunately, however, the clicked position may be adjusted somewhat to the value of θ at which C is a maximum to produce a very low value of $dC/d\theta$ throughout the considerable angular excursions given in the magnified inset curve

The total edge capacitance for the condenser is

$$C_E=C_{E(l)}+C_{E(t)},$$

$$C_E=\frac{M}{7\cdot2\pi}(\log_e R_m-\log_e r)[\cot\tfrac{1}{2}(k-\theta)+\cot\tfrac{1}{2}(\theta+k)],$$

$$\frac{dC_E}{d\theta}=\frac{M}{14\cdot4\pi}(\log_e R_m-\log_e r)[\operatorname{cosec}^2\tfrac{1}{2}(k-\theta)-\operatorname{cosec}^2\tfrac{1}{2}(\theta+k)] \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Let

$$K=\frac{M}{14\cdot4\pi}(\log_e R_m-\log_e r)$$

$$\frac{dC_E}{d\theta}=K\left[\frac{1}{\sin^2\tfrac{1}{2}(k-\theta)}-\frac{1}{\sin^2\tfrac{1}{2}(\theta+k)}\right]$$

$$\log_e\frac{dC_E}{d\theta}=\{\log_e K-2\log_e\sin\tfrac{1}{2}(k-\theta)\}-\{\log_e K-2\log_e\sin\tfrac{1}{2}(\theta+k)\}$$

$$\frac{1}{\frac{dC_E}{d\theta}}\cdot\frac{d^2C_E}{d\theta^2}=\frac{\cos\tfrac{1}{2}(k-\theta)}{\sin\tfrac{1}{2}(k-\theta)}+\frac{\cos\tfrac{1}{2}(\theta+k)}{\sin\tfrac{1}{2}(\theta+k)}$$

$$\frac{d^2C_E}{d\theta^2}=K\operatorname{cosec}^2\tfrac{1}{2}(k-\theta)\cot\tfrac{1}{2}(k-\theta)+K\operatorname{cosec}^2\tfrac{1}{2}(\theta+k)\cot\tfrac{1}{2}(\theta+k)$$

$$\doteqdot K\operatorname{cosec}^3\tfrac{1}{2}(k-\theta)+K\operatorname{cosec}^3\tfrac{1}{2}(\theta+k)$$

$$\doteqdot\frac{M}{14\cdot4\pi}(\log_e R_m-\log_e r)[\operatorname{cosec}^3\tfrac{1}{2}(k-\theta)+\operatorname{cosec}^3\tfrac{1}{2}(\theta+k)] \quad . \quad . \quad . \quad . \quad . \quad (7)$$

for the small angles which are likely to be associated with this problem.

These two expressions are useful to the designer in assessing the capacitance uncertainties likely to be associated with inaccurate zero setting. They combine the edge capacitance effects of both leading and trailing edges. At exact zero θ_0, when

$$k-\theta=\theta+k$$

$$\theta=0$$

$$\frac{dC_{E(0)}}{d\theta}=\frac{dC_{E(l)}}{d\theta}+\frac{dC_{E(t)}}{d\theta}=0$$

and

$$\frac{d^2C_{E(0)}}{d\theta^2}\doteqdot\frac{M\operatorname{cosec}^3\tfrac{1}{2}k}{7\cdot2\pi}(\log_e R_m-\log_e r) \quad . \quad . \quad (8)$$

where

$$k=\tfrac{1}{2}\{2\pi-(\psi+\phi)\}.$$

The single evaluation of this expression is all that is needed to assess the degree of capacitance stability of zero setting.

Although $dC_{E(0)}/d\theta$ is zero at $\theta=0$, it will be found that $d^2C_{E(0)}/d\theta^2$ has a very high value at this setting and, consequently, for quite small angular displacements of the moving plate system from the exactly symmetrical position the capacitance changes alarmingly, as is shown by the heavy continuous curve of Fig. 19.

If this curve is compared with that of Fig. 13, it will be seen that the benefits of the precise compensation of the edge capacitance at the 100$\mu\mu F$ setting are swamped by the greater capacitance uncertainty of the zero setting from which there is no escape. It is seen that the only true criterion of a stable zero capacitance setting is the value of $d^2C_{E(0)}/d\theta^2$ as computed from expression (8), which, in this example, is nearly 0·9,

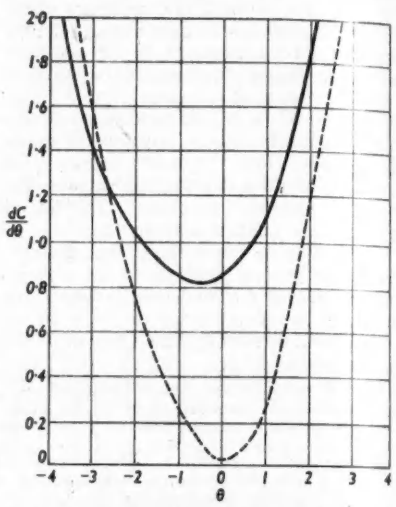


Fig. 18—Curves showing the success attending the author's attempt at complete compensation of the residual $dC/d\theta$ of the decade air condenser. The example given here is that of the third (300$\mu\mu F$) position of the decade

whereas if the capacitance is to be really stable for a degree of arc on either side of θ_0 the value must be reduced to the order 0·03.

From sheer necessity, therefore, the author was forced to devise a method of compensating, automatically, the resultant effective $dC_{E(0)}/d\theta$ throughout a small angle of a degree or so on either side of the zero setting. After computing from (6) the capacitance slope to be compensated, the author felt that an equal and opposite effect could be obtained by mounting on the main condenser spindle a single moving plate of

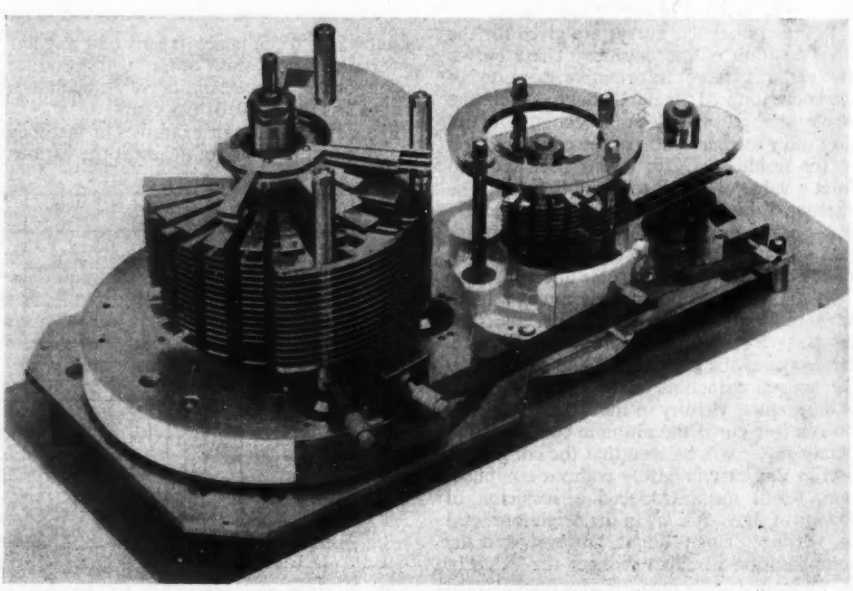


Fig. 17—The plate systems of a three-dial air condenser comprising two decades and a continuously variable unit. The premier decade seen on the left is that described in the present article and is followed by another decade of less massive construction, the fixed plates of which also provide one plate system of the continuously variable condenser on the extreme right of the illustration

radius R_m, but of small angular extent‡ and arranging this to be interleaved between and exactly coincident (angularly) with two fixed plate sectors having the same angular extent. It is seen that any angular move-

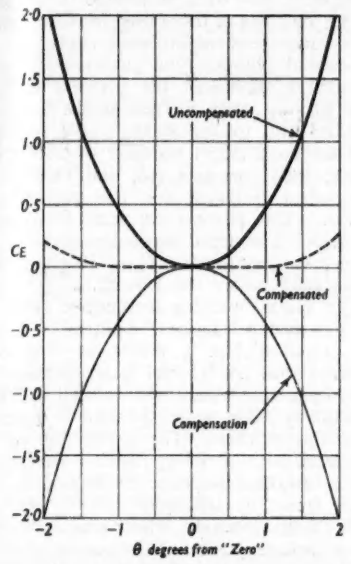


Fig. 19—Curves which show the compensation of the capacitance change with small angular displacements in the vicinity of the "zero" capacitance setting. The heavy continuous line curve shows the capacitance change obtained normally without compensation and the light curve that which is introduced to compensate it. That the compensation is efficacious is shown by the broken line curve which, although plotted from the results of careful measurement, agrees closely also with the algebraic sum of the other two curves

ment, positive or negative, from the precise zero decade setting will reduce the capacitance of this additional device.

It was thought that the fringing field at the radial edges of this auxiliary condenser would delay the reduction of capacitance sufficiently to provide the required "law" of

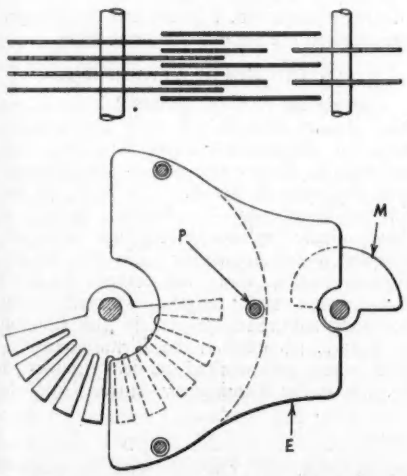


Fig. 20—Showing the use of a single plate system to serve as the fixed plates for both decade and continuously variable units of the complete condenser. The supports *P* are the only members which need be insulated by solid dielectric material

compensation at least throughout ±1 deg. of arc. This proved to be the case and, with very little trial and error plate shaping, the compensating negative capacitance shown by the light continuous curve of Fig. 19 was obtained. That the degree of compensation was complete is shown clearly by the resultant capacitance (broken line) curve, which is, of course, the algebraic sum of the other curves. This means that the angular uncertainty of the zero position of the decade cannot affect the accuracy of any other position.

Thus the final imperfection of the principle having been eliminated, a decade of air capacitance has been provided in which the calibration is sensibly independent of angular setting uncertainties.

Having described the principle of the air decade and the degree of perfection attained, the author would like to add a few notes on the application of such a standard.

The capacitance of the decade condenser may be still further and continuously subdivided by means of an *ordinary* variable air condenser without the introduction of any solid dielectric material and, therefore, without augmentation of dielectric loss. The three conducting pillars on which the fixed plates are mounted and which are themselves mounted on silica insulators, also mount the fixed plates of the variable condenser. In fact, in the author's condenser, certain of the fixed plates of the decade shown in Fig. 4 are extended to form the fixed plates of the variable condenser as shown at *E* in Fig. 20, thus obviating the necessity for additional solid dielectric material. The author's preferred view is that the solid dielectric which would be necessary for supporting and insulating the three fixed system pillars of the simple continuously variable air condenser are all that are necessary for the complete condenser combination so that, in effect, the decade extension is added without the slightest augmentation of power factor—a far different story from that depicted in Fig. 3.

It may be argued that despite the decade system one still has, finally, to read the scale of a variable condenser. But the decade having, in effect, reduced the capacitance of the variable condenser to one-tenth of its value the scale dividing becomes a simple matter, both for the engraver to execute and the user to read, since the accuracy demanded of the scale is also only one-tenth of that of a scale of an entirely orthodox variable condenser.

It may be thought by some readers that one-tenth of the original accuracy is insufficient to greatly simplify the ultimate scale and that to them the argument has failed. To meet this objection, the author has added a second air decade to that already described. This, naturally, has ten increments of $10\mu\mu F$, and, because of the much smaller capacitance demanded of its plate systems, is of much smaller bulk than that of the premier decade. The plate shapes are similar and the same order of percentage residual $dC/d\theta$ is obtained, but it is thought unnecessary to employ compensation in order to reduce these residual slopes as they are, in any case, only one-tenth of those of the premier decade. The high potential (fixed) plate system of this second decade also provides the fixed plates for the ordinary variable air condenser, which is incorporated to give ultimate continuous subdivision of capacitance with the extremely simple scaling shown already in Fig. 2—some measure of the simplicity may be conveyed by the fact that the accuracy of dividing and reading is reduced to one-hundredth by the provision of the two preceding decades.

Generally, the author prescribes range extension by a single decade for accuracies of 0·1 per cent or so, while accuracies up to 0·01 per cent are possible by the provision of two decades.

The latter example of the decade air condenser is illustrated in Fig. 17, in which most features are to be seen with the exception of the radial compensating slots in the fixed plates of the premier decade; these are concealed beneath the heavy end plates between which the fixed plates are rigidly sandwiched.

In conclusion, the author expresses the hope that this principle of decade air capacitance has provided the scaling simplification so badly needed in industry and for which he has had so many requests. His acknowledgments are due to H. W. Sullivan, Ltd., his co-patentee.

‡ Of small angular extent so as to augment the minimum capacitance of the condenser as little as possible.

Notable Locomotives of 1906

By E. C. POULTNEY, O.B.E.

No. I.

PRECEDING articles contributed to THE ENGINEER recalling past developments in locomotive practice followed by British railways have recorded a striking increase in the adoption of six-coupled engines intended for fast passenger services and the general introduction of large boilers carrying, in some instances, higher working steam pressures. Further, the subject of boiler design, particularly when considered from the point of view of increased steam pressures, received attention, perhaps more especially by G. J. Churchward at Swindon, whose well-known paper entitled "Large Locomotive Boilers," read before the Institution of Mechanical Engineers in 1906, will always be regarded as being one of the classics. The importance of this contribution to the subject was fully emphasised by the ensuing discussion, and no doubt readers of THE ENGINEER will be interested to be reminded that amongst the notable engineers taking part was Vaughan Pendred, who was then the editor of that journal and who, in the course of his remarks, suggested that some benefit might be obtained if boiler feed water could be arranged to enter the boiler through the steam space.

When replying to the discussion, Churchward said he would try this method, which he eventually did, and in so doing inaugurated a means for supplying boiler feed water which became standard practice at Swindon and has since been widely taken up by many railways in different parts of the world.

Churchward's paper recorded more particularly the work done under his supervision at Swindon, which, it may be recalled, has been more recently sketched in an informative manner by K. J. Cook in a paper communicated to the Institution of Locomotive Engineers in 1950. This presented an interesting account of the evolution of boiler design as practised at Swindon, and appears to bring out the fact that Churchward's standard form of construction is based to a large extent on a design evolved by the Brooks Locomotive Works, Dunkirk, N.Y., U.S.A., and used for locomotives built for the Great Northern and Illinois Central Railways during the later years of the last century.

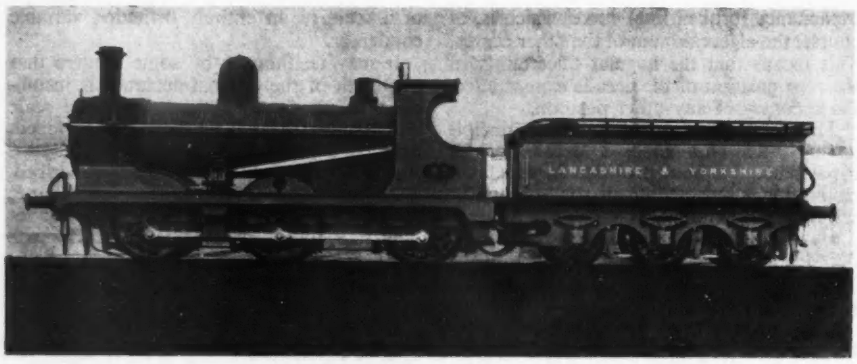


Fig. 1—Hughes's superheater freight engine, 1906

In passing, it may be of interest to recall that the builders' chief engineer at the time was that engineering genius, John Player, who was responsible for the high-speed "Prairie" type engines of the Lake Shore and Michigan Central, put into service at the turn of the century.

Interesting as the successive developments chronicled by former articles undoubtedly were, 1906 will always stand out as being especially noteworthy on account of the fact that this year saw the first applications of the Schmidt flue tube superheater to British locomotives. Thus, the present year sees the completion of fifty years of locomotive superheating, certainly one of the greatest single improvements made in locomotive engineering.

Further advances made in 1906 include the completion at Swindon of the first of Churchward's four-cylinder simple expansion express passenger locomotives, No. 40, "North Star," destined to be the prototype of a long line of eminently successful locomotive classes, terminating with C. B. Collett's "King" class of 1927.

Looking back half a century and briefly summarising some of the other developments claiming attention, include the experimental application of the compound principle on the Lancashire and Yorkshire and the building of the two large four-cylinder compound locomotives by W. Worsdell at Gateshead, for service on the North Eastern Railway. On the Caledonian and North British Railways, locomotives of high power were introduced, on the former for both passenger and freight traffic and on the latter for passenger services, in the form of a large "Atlantic" design, the first and only example of this type to be specifically built for a Scottish railway, and at the same time for general main line freight traffic an enlarged design of the 0-6-0 type was introduced to a design prepared by W. P. Reid at their Cowlairs Works.

The principal dimensions of the several examples of locomotives constructed during the period now under review will be found in Table II and will be referred to in the order in which they are given.

The First Schmidt Superheater

The first applications of the Schmidt superheater were made on the Lancashire and Yorkshire, for which line George Hughes at Horwich fitted two 0-6-0 type engines (Fig. 1) of a standard design with eighteen-element superheaters, and at the same time G. J. Churchward, of the Great Western Railway, fitted the first engine of a series of ten of his highly successful 4-6-0 type express locomotives, No. 2901, "Lady Superior," with a twenty-four-element superheater. For convenience, Table I has been prepared, giving the principal dimensions of both the non-superheater and superheated engines of the types and classes used by both the railways concerned.

The information thus given shows how the addition of the superheater affects the disposition of the boiler heating surfaces and the empty and loaded weights of the engines.

Referring to the L. and Y. engines, Hughes fitted the superheater engines with enlarged cylinders and piston valves, which were arranged for inside admission and were operated by the existing Joy's valve gear through the medium of rockers operating in the horizontal plane, necessary because the valves were above the cylinders, but offset towards the outside. The radius rods of the valve gear were pin-jointed to spindles, taking the place of those used for the original slide valves and which were supported by substantial plunger type guides working in cylindrical guides in the cylinder casting. The rockers were link-connected to these spindles and to the piston valve spindles. The standard steam pressure of 180 lb per square inch was retained, and mechanical lubrication provided for the pistons and valves. The piston-rods were fitted with tail rods. The detail particulars given in the table have been taken from Hughes' 1910 paper read before the I.Mech.E.

The Great Western locomotive (Fig. 2), the first of ten "Ladies" built in 1906, had the standard No. 1 boiler as then constructed, but the normal steam pressure of 225 lb per square inch was reduced to 200 lb and the cylinders were increased in diameter from 18in to 18½in. The superheater header was fitted with a sliding pattern of regulator valve. In other respects, this engine did not differ from the standard "2900" class as built at that period. The particulars given show the arrangement of the heating surfaces of the Swindon No. 1 boiler and the changes made when the superheater was fitted.

TABLE I—*Comparative Dimensions of Non-Superheater and Superheater Locomotives: Lancashire and Yorkshire and Great Western Railways*, 1906

Railway	Lancashire and Yorkshire		Great Western	
Type	0-6-0	0-6-0	4-6-0	4-6-0
Service	Freight	Freight	Passenger	Passenger
Cylinders, No., diameter and stroke, inches	Two, 18×26	Two, 20×26	Two, 18×30	Two, 18½×30
Driving wheels, diameter, inches	61	61	80·5	80·5
Steam pressure, pounds per square inch	180	180	225	200
Tubes, No. and diameter, outside, inches	207—1¾	106—1¾	250—2	130—2
Flues	—	18—4¾	—	24—4¾
Superheater pipes, diameter, outside, inches	—	54—1⅛	—	96—1¼
Heating surfaces, square feet :				
Tubes and flues	1,022·5	762·5	1,988·65	1,485·96
Firebox	107·6	108·1	154·26	154·94
Evaporative, total	1,130·1	870·6	2,191·91	1,630·90
Superheater	—	191·1	—	307·52
Combined	—	1,061·7	—	1,948·42
Grate area, square feet	18·75	18·75	27·07	27·07
Tractive force, pounds at 85 per cent B.P.	21,200	31,200	23,090	22,649
Weights, tons :				
Engine :				
Empty	38·9	40·95	63·85	66·0
Full	42·15	44·25	70·2	72·0

London and North Western Railway

Considering now the different locomotives built during 1906 in the order given in the table of dimensions (Table II), those first claiming notice are two new classes designed and constructed for the L.N.W.R. at the Crewe Works by G. Whale, the Chief Mechanical Engineer. The first is a six-coupled 4-6-0 engine for main line general freight traffic, and the other a large 4-4-2 side tank engine specially built to work suburban services in the London area and also used in the Birmingham district, where they worked the heavy passenger service on the Birmingham–Sutton Coldfield

TABLE II—*Notable Locomotives of 1906: Principal Dimensions*

Railway	L.N.W.R.	L.N.W.R.	L. & Y.R.	N.E.R.	G.W.R.	G.C.R.	S.E. & C.R.	C.R.	C.R.	C.R.	N.B.R.	N.B.R.
Type	4-6-0	4-4-2.T	0-8-0	4-4-2	4-4-2	4-6-0	4-4-0	4-6-0	4-6-0	4-6-0	4-4-2	0-6-0
Cylinders, No. diameter and stroke, inches	Two 19×26	Two 19×26	Two H.P. 15½×26 Two L.P. 22×26	Two H.P. 14½×26 Two L.P. 22×26	Four 14½×26	Two 19½×26	Two 19½×26	Two 20×26	Two 19×26	Two 19×26	Two 20×28	Two 18½×26
Driving wheels, diameter, inches	63	75	53·5	85·25	80·5	78	78	78	69	63	81	60
Steam pressure, pounds per square inch	175	175	180	225	225	200	180	200	180	180	200	180
Rated tractive force, pounds	22,150	18,600	—	—	25,200	21,600	18,860	22,620	20,812	22,150	23,500	22,800
Heating surfaces, square feet :												
Tubes	1,840	1777·5	1,767	1,916	1988·65	1777·9	1,396	2117·5	2,050	1,895	2071·4	1,462
Firebox	144	161·5	147	180	154·26	133·1	136	148·25	128	128	184·8	143
Total	1,984	1938·0	1,914	2,096	2142·91	1911·0	1,532	2265·75	2,178	2,023	2256·2	1,605
Grate area, square feet	25	22·4	23·05	29	27·07	26	21·15	26	21	21	28·5	19·8
Weights in working order, tons :												
On driving wheels	44	39·5	60·8	39·15	39·6	54·5	34·9	55	49	45·9	40	50·35
Engine	63	74·75	60·8	73·6	74·5	70·5	52·25	73	64	60·4	74·4	50·35
Tender	39·25	—	41·65	42·0	40·0	44·5	—	57	38	38·0	45·4	38·0
Total	102·25	74·75	102·25	115·6	114·5	115·0	—	130	102	98·4	119·8	88·35

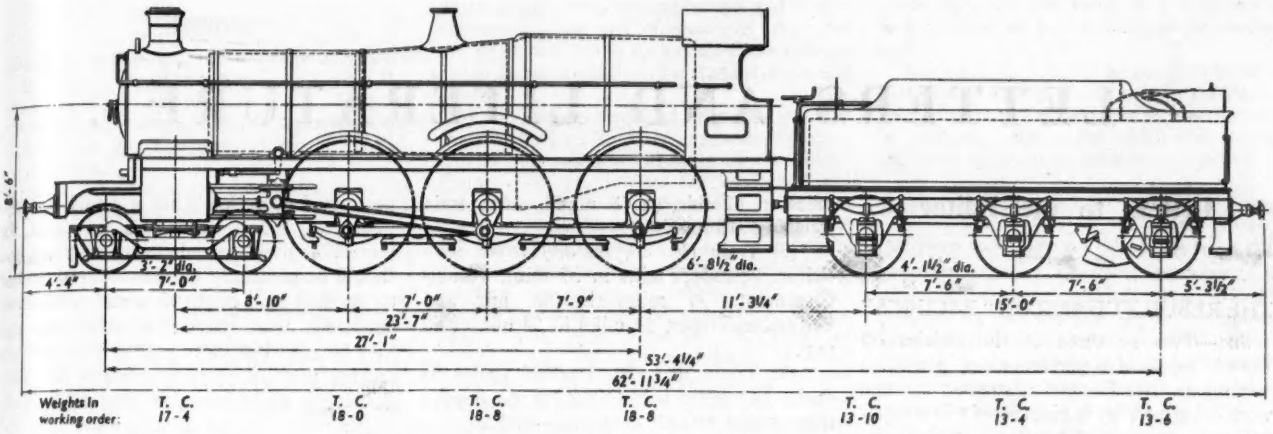


Fig. 2—Churchward's superheater engine "Lady Superior." 1906

line. In general, both of these locomotives resembled very closely others designed by Whale, in the first place in 1904, when the 4-4-0 "Precursor" class appeared, and in the following year when the six-coupled 4-6-0 "Experiment" class, also built for passenger service, came out.

The new six-coupled freight engines were almost a copy of the "Experiments," but with 63in in place of 75in drivers, while the

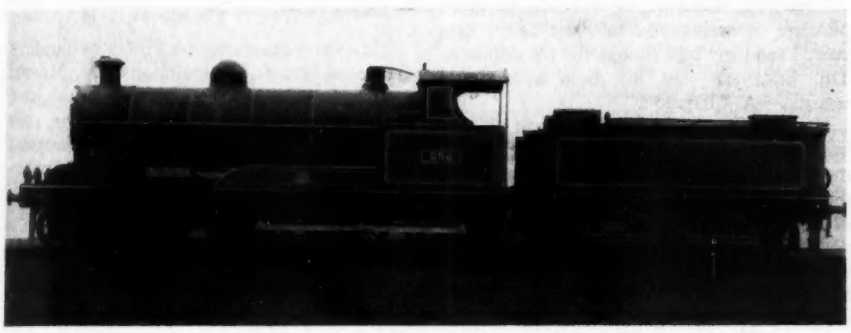


Fig. 3—Whale's six-coupled freight locomotive, L.N.W.R.

tank engines were so similar to the 4-4-0 passenger engines that they became generally known as "Precursor tanks." All the engines had inside cylinders, 19in by 26in, with balanced slide valves in overhead valve chests, operated by Joy's valve gear. They were further alike in all having built-up balanced crank axles and the central supporting bearing between the cranks, introduced in the first instance by F. W. Webb and retained, so far as the writer is informed, for all Crewe-designed locomotives up to the end of the Crewe era, about 1923. The new freight engines had boilers as used for the "Experiments," except that the fireboxes were rather larger, and those for the passenger tank engines were duplicates of those fitted to the "Precursor" class and had coupled wheels 75in diameter, as for the "Experiments." These tank engines were, when first turned out, certainly amongst the largest of this design in the country, with a full weight of 74 to 75 tons, 39·5 tons of which rested on the four coupled wheels. When first built, the new engines carried the standard working steam pressure of 175 lb per square inch, though the writer thinks this was increased later to 180 lb or 185 lb per square inch. The six-coupled engines seem to have been found generally useful and ultimately numbered about 170 engines.

As Figs. 3 and 4 show, both were extremely neat in appearance, like the "Precursors" and "Experiments."

Lancashire and Yorkshire Railway

Developments initiated by George Hughes at Horwich, as already mentioned, consisted of the experimental application of the Schmidt flue tube superheater and the introduction of compound locomotives.

In order to appreciate the reasons prompting consideration being given to compound expansion and particularly its application to engines used in freight as opposed to those for passenger traffic, it will be necessary to refer to Hughes's paper of 1910 on the subject of compounding and superheating locomotives, from which it will be learned that the arguments advanced in favour of compound freight engines rather than those used in passenger service were based on certain facts established by observations and which were (1) engines in freight traffic normally worked at longer rates of "cut-off" in the region of, say, from 30 to 45 per cent compared with those in passenger service, which were found to run with a "cut-off" of 20 per cent, and (2) freight engines operated at lower speeds, meaning that piston speeds were normally much lower than was the case with passenger engines. It was therefore considered that, by the application of compound expansion to freight locomotives, expansion ratios would be increased and heat losses to cylinder walls, accentuated by relatively low piston speeds, would be reduced by lessening the difference between admission and exhaust pressures and temperatures in the cylinders.

It is of interest to observe that the opinions expressed by Hughes respecting the desirability of compounding of freight engines rather than those used in passenger service would seem to be contrary to those more generally held; for instance, by F. W. Webb and T. W. Worsdell, who had compounded both passenger and freight engines on the L. and N.W. and N.E. Railways, and by S. W. Johnson and, later, by R. M. Deeley of the Midland, who applied compound expansion to express locomotives only, while at the same time Churchward's experiments on the Great Western Railway with compounds were also confined to passenger engines. In this connection mention may also be made of the fact that Hughes's predecessor, H. A. Hoy, had, in 1901, converted a standard 4-4-0 passenger engine to compound expansion by replacing the two existing cylinders by four, two h.p. and two l.p., the latter being outside and the former inside under the smokebox and in line transversely with the outside pair. As a compound this engine ran till 1908, when it was reconverted to simple expansion and at the same time fitted with a superheater. It is not without interest to note that no mention of this compound was made in the paper of 1910, even though it was largely devoted to the subject of compounding locomotives.

(*To be continued*)

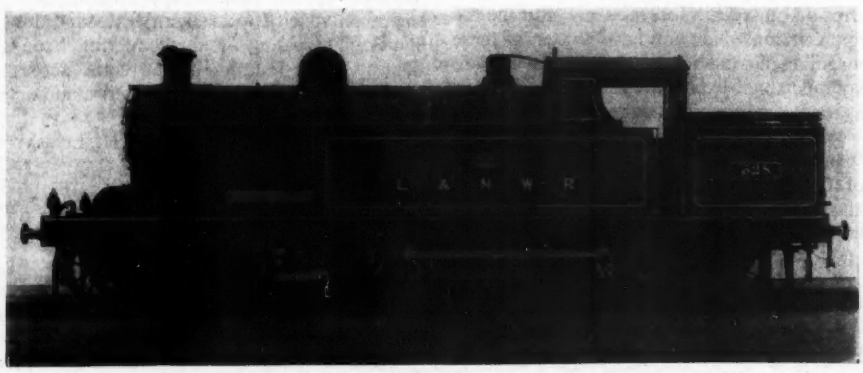


Fig. 4—Passenger tank engine designed by G. Whale for the L.N.W.R.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

THE REBUILT CHAPELON "PACIFICS"

SIR,—Two or three of the articles on French locomotive performances, published recently in THE ENGINEER, stressed the fine work being done by engines rebuilt in accordance with Monsieur Chapelon's conceptions, which resulted in their efficiency being raised so considerably that they became capable of remarkable work with heavy trains timed at high speeds; performances which at first sight would appear altogether beyond the capacity of elderly machines such as these, of moderate dimensions and weight. The fact that they do these performances without difficulty, and have done so for many years, goes to prove not only the correctness of "Chapelon principles," but in addition the wisdom of rebuilding and bringing up to date engines that otherwise might be, as it were, a limited liability rather than an asset. It would appear a pity that more of this rebuilding has not been done in Britain, to give a fresh lease of life to outmoded engines of low efficiency.

I would like to quote an interesting letter on this subject received recently from Monsieur Chapelon, first pointing out that the wording here and there calls for a little clarification, in that it was penned under the impression that I was in British Columbia, whereas actually I was in England, and on the point of making the visit to France which he courteously suggests. In view of Monsieur Chapelon's intimate connection with these rebuilt engines, his remarks naturally have indisputable weight; my only criticism of his letter is that he gives undue credit to my endeavour to portray some of the fine performances of these outstanding locomotives. Extracts from Monsieur Chapelon's letter follow.

"... Returning from holiday after several weeks' absence, I have the agreeable surprise of finding on my desk THE ENGINEER for August 10 and 17, in which I have read with eagerness and, it goes without saying, sustained interest, the first reports, so remarkably presented and written, of your trips on our rebuilt locomotives. For me the appreciation which you have written of these machines has an inestimable value, because your personal experience is so authoritative as to give me complete satisfaction.

"I hope that next year you will be able to spend part of your time riding on some other of the fastest of our steam trains, which, alas, are getting scarcer each day, because of an obtuse policy of extreme electrification and 'dieselisation.'

"Amongst the most interesting trains this summer were :—

(1) Train No. 41, Troyes to Vesoul, with Paris/Troyes at 65 m.p.h. (103 miles in 95 min), Troyes/Chaumont (59 miles in 56 min at 63·5 m.p.h., and Chaumont/Vesoul (73·7 miles in 62 min at 68 m.p.h., each train weighing 310 tons.

"(2) Train No. 46, Belfort/Troyes, with Belfort/Vesoul (38 miles in 37 min), Vesoul/Chaumont, 74 miles in 68 min and Chaumont/Troyes, 59 miles in 54 min at 66 m.p.h.

"(3) Train No. 120, Enghien (pass) to Paris, 143 miles in 138 min at 62 m.p.h., train weight 460/520 tons [net—E.H.L.].

"(4) Train No. 102, Rouen/Paris (Saturday), 86·5 miles in 76 min, 68 m.p.h., with 380/400 tons.

"(5) Train No. 121, Paris/Rouen, in 69 min at 65·5 m.p.h., with 380/400 tons.

"(6) No. 719, Mans/Ancenis (Nantes), with a stop at Angers, at 63 m.p.h., with 430/480 tons, as well as between Le Mans and Angers, 60 miles and 33 miles.

"(7) Bordeaux/Marmonde, Train N.3001, 50 miles at 64 m.p.h. with 260/300 tons, and vice versa, No. 3002, in 47 min at 62 m.p.h.

"Hoping, therefore, of having the great pleasure of seeing you in Paris again next year, I send my best thanks for the copies of THE ENGINEER and my best wishes and regards.—A. Chapelon."

Having recently returned from an all-too-brief visit to France and the S.N.C.F., I can mention a perfect example of what these oldish rebuilt Chapelon "Pacifics" are called upon to do, which, thanks to the courtesy of my friends in Paris, I was enabled to observe from the cab. A four-cylinder compound "Pacific," taken "from stock" at the Lille depot, reached and held for several miles a speed of 102 m.p.h., while pulling two 50-ton coaches, and pushing a 120-ton "dead" electric locomotive, the run being to test the riding and pantograph of the latter. The steam locomotive was in the capable hands of Monsieur Leseigneur, Chief of Traction, Nord Division. This happened to be the highest speed I have ever experienced on a steam locomotive; this fact, and the peculiar make-up of the train, making the experience doubly interesting. The engine was in no way specially prepared, being one of a considerable number at Lille, any of which can be, and are, called upon to do these runs, and reach 102 m.p.h. Incidentally, the Flaman recorder only registers up to 160km, 100 m.p.h.; the engine on which I rode slightly exceeded this figure. The riding—well, wonderful "considering," but I admit having come across machines on which it was easier to maintain balance!

EDWARD H. LIVESAY

Croydon, November 1, 1956.

GEAR STANDARDS

SIR,—Our attention has been drawn to your recent article by Dr. H. E. Merritt on gear standards, and to the less well-informed editorial on the same subject. It is true that drafting of the revisions of standards now in hand is proving a somewhat difficult and protracted operation; but it would be quite wrong to deduce from this fact that the standards have served their purpose and should be gracefully buried. We would like to say on behalf of the technical committees concerned with these gear standards that they have a quite clear goal in view and are making positive progress towards it. That goal is the preparation, as soon as possible, of draft revisions of existing standards and of new standards for gears. How soon this can be achieved depends to some extent on the progress made by the international technical committee in its work on the accuracy of gears, which affects B.S. 436.

G. WESTON,
Technical Director,
British Standards Institution.

November 12, 1956.

CALCULATION OF BACKLASH BETWEEN GEAR-TEETH

SIR,—In commenting on Professor Tuplin's article on backlash calculations, Dr. Merritt gave expressions for an exact alternative solution in your September 28 issue, but he did not reduce them to their simplest terms. For spur gears he sets out the problem thus :—

$$K = C/e.$$
$$\Omega = 2[K^2 \cos \psi_g \,(\text{inv}\, \psi_e - \text{inv}\, \psi_g) - K \sin \psi_g].$$
$$z_0 = e\Omega/K.$$

It will be noticed that K appears twice in the bracket expression and again once in line 3. It can be divided out and remain in only one place :—

$$z_0 = 2C[\cos \psi_g(\text{inv}\, \psi - \text{inv}\, \psi_g) - \sin \psi_g/K].$$

Symbols that seem preferable to the writer are as follows :—

ΔC, the change in centre distance, instead of e.
$\Delta C/C$ instead of $1/K$ (which is a *small* value).
ϕ instead of ψ for pressure angle.
Δ inv ϕ as a shorter form of inv ϕ_e − inv ϕ_g.
B_b instead of z_0 for the backlash in the direction normal to the profiles and also as existing at the base circles.

We can then write :—

$$B_b = 2C\left(\cos\phi \,.\, \Delta\,\text{inv}\,\phi - \frac{\Delta C}{C}\sin\phi\right).$$

The value in the brackets is dimensionless and can be tabulated or graphed for any pressure angle; it becomes zero when $\Delta C = 0$. The symbols convey the meanings of the terms; this is essential if the calculator is not to become a mere figure-nudger. All these things should be set out in such a way that he is able to see, in his mind's eye, just what is happening, on the gear or machine, to reduce the drudgery of routine calculation and the possibility of mistake. It should be noted that neither of the methods proposed conform to Professor Tuplin's implied conditions of no tables and no graphs.

A. M. GUNNER

Hampton Wick,

November 18, 1956.

Literature

Disposal of Sewage and Other Water-borne Wastes. By DR. KARL IMHOFF, DR. W. J. MULLER and D. K. B. THISTLETHWAYTE. Butterworth's Scientific Publications, 88, Kingsway, London, W.C.2. Price 45s.

THIS book is based on a translation of the sixteenth edition of Imhoff's *Taschenbuch der Stadtenwaesserung*, the first edition of which appeared in Germany in 1907, and the first translation into English, in America in 1929, under the title *The Arithmetic of Sewage Treatment Works* by Imhoff and Fair. A further book by Imhoff and Fair appeared in 1940, entitled *Sewage Treatment.* Although of similar origin, these three books are very different in character and in size, for, as will be remembered, *The Arithmetic of Sewage Treatment Works* was a small work devoted to calculations, and *Sewage Treatment* was brought to a form that suited it to American conditions by Professor Gordon M. Fair. In case the title of this new publication should be misleading, let it be stated that this, like the previous works, is a typical textbook dealing with sewage treatment in the main and having one chapter only covering the various kinds of trade wastes most frequently encountered at the present day : it is not a specialist work describing at length the numerous and intricate problems of industrial waste disposal. The book is divided into four parts : Introduction and Basic Data ; Methods of Disposal ; Treatment of Sewage and other Water-borne Wastes, and Disposal and Treatment of Water-borne Wastes from Residences and Institutions in Unsewered Areas. There is an authors' index and an ample subject index ; also lengthy bibliographical references occur at the ends of chapters.

The first part contains four chapters, the first being virtually a third preface ; the second dealing briefly with sewerage and drainage ; the third with qualities of wastes, and the fourth with laboratory examination. This last is devoted almost entirely to solids content, biochemical oxygen demand and oxygen absorbed tests. There is some reference to bacteriological examination but very little to the other tests normally applied to sewages, wastes and effluents.

The next part deals, in four chapters, with general considerations ; disposal into natural waters ; disposal on to the land, and reclamation of water and other constituents in sewage and waste. The main body of the study of treatment is covered by eight chapters in the following part, which deal with general considerations ; mechanical, chemical and biological processes ; sludge treatment ; treatment of industrial wastes ; works design details, and example calculations. The final section follows the example of other recent writers in including, at the end of a work on sewage treatment, the special problems of treatment of discharges from isolated buildings. This contains two chapters. There are seventy-two line diagram illustrations, clear but mostly small, and thirty-three tables.

Dr. Karl Imhoff is one of the more important writers of international reputation and has made well-known contributions to the science of sewage disposal. His work is based on long experience, wide study and originality : this book will, therefore, be welcomed by all specialists, including scientists, engineers, chemists and sewage works operators. The text of the book is clear and readable and contains much information not easily found elsewhere. It is at its best where the nature of sewage, methods of chemical examination and processes of treatment are described, for it makes all these matters easily understandable to the student or general reader.

It has been complained, with justice, that for many years English engineers followed closely the recommendations of the Royal Commission on Sewage Disposal, and did not keep contact with work in foreign countries, with the result that English practice fell behind the times. This has been largely remedied by the wide reading of American journals, proceedings and textbooks, and several works are now influenced by American ideas. But, apart from what we know of German practice, our knowledge of what goes on in Europe is very sparse indeed. The chief value of books by overseas writers, therefore, lies—as far as English readers are concerned—in what they can tell us of methods different from those in common use in England.

In this respect the book can be criticised, for, as stated in the preface, the contents have been made to differ " from the German work in order to make it more suitable for use in the countries of the British Commonwealth, where natural conditions and tradition call for some modifications from practices common in Europe." This, one feels, is an error of policy.

The writer or translator who attempts to produce a technical work for the benefit of specialists outside his own country is in danger of making grave errors, for he can never obtain a true picture of conditions overseas, and has still greater difficulty in keeping up to date. This book, despite all its qualities, is by no means free from the faults that its professed approach make unavoidable. Where specific references are made to English practice, there are more erroneous or at any rate misleading statements than those which are strictly accurate. More particularly, the reader is presented with the difficulty of deciding for himself whether any particular item of practice is German, supposed English, United States, or perhaps Australian.

The final chapters, which cover conservancy sanitation and small treatment works for premises in unsewered areas, give the impression of having been built up from a study of world literature in the English and German languages. The very marked differences between English practice and that of the United States and some other countries do not appear to have been appreciated, and, as regards the former, the more valuable contributions to literature appear to have been overlooked. In this connection it might be mentioned that, in many parts of the world, it is practicable to soak away small quantities of sewage with little or no treatment—consequently research has been directed towards this end : whereas in Great Britain, where many deaths have been caused by the sewage pollution of wells, research has been aimed at the production in small works of high-quality effluents fit for discharge to watercourses or, only where watercourses do not exist, by soakage into the ground.

A defect of the book from the point of view of the engineer engaged on design is the omission of essential formulæ and design techniques. To give one example, the proportional-flow weir for control of grit channels is mentioned and illustrated, but the means by which its proportions are calculated are not described. The example calculations to which Chapter 16 is devoted are elementary and in some respects totally inadequate. Speaking metaphorically, one could say that this book is a high-quality tool but one that has not been given a cutting edge.

The publishers are to be congratulated on the quality of the production. The text is printed in the very readable Baskerville type on a sound white paper which also sets off the illustrations to the best advantage.

Aberrations of Thin Lenses. By H. H. EMSLEY. Constable and Co., Ltd., 10, Orange Street, London, W.C.2. Price 50s.

PROFESSIONAL lens designers are very much preoccupied at the present time with the possible application of digital computing machines to the tracing of rays through lens systems, to the evaluation of lens aberrations and, indeed, to the automatic design of corrected lenses. The form in which the data have to be prepared for programming these machines can be very curious indeed, and it is by no means clear which optical formulæ are likely to prove best adapted to these new computing techniques.

It might therefore seem inopportune to bring out a new book on lens aberrations based on Conrady's somewhat out-dated treatment and nomenclature, and in which the old-fashioned log-book methods of ray tracing are employed. Yet there may be many people interested in lens calculations who have neither the mathematical equipment nor the financial resources to consider using computing machines, to whom the book will appeal.

Certainly the reviewer, himself a former student of Conrady's, is prepared to pay tribute to the value of the methods both for illustrating the fundamentals of the problem and for carrying through a design. There may be quicker methods, but Conrady himself was such a speedy and accurate computer and had such a natural flair for finding short cuts, that in his case at least, the overall computing time was reduced to reasonable proportions.

This book, then, is likely to find many readers who will study its pages with profit and pleasure. It is well-written, although the occasional intrusion of phrases such as " this design work is intricate and demands much skill, experience and patience," can prove irritating, since it tells nothing and suggests a kind of forbidden territory into which only the initiated may enter. Then, when the author discusses the distribution of light in optical instruments, he does not appear to understand the full implications of the subjective concept of " luminosity," since, on page 316, he refers to improving the luminosity of the image in a non-visual instrument.

But these are trivial criticisms of a book which among a certain circle of readers will meet with general approval.

Books Received

Pul[illegible]nd Digital Circuits. By J. Hillman and H. T[illegible] McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, London, E.C.4. Price 94s.

Transistors in Radio and Television. By M. S. Kiver. McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, London, E.C.4. Price 37s. 6d.

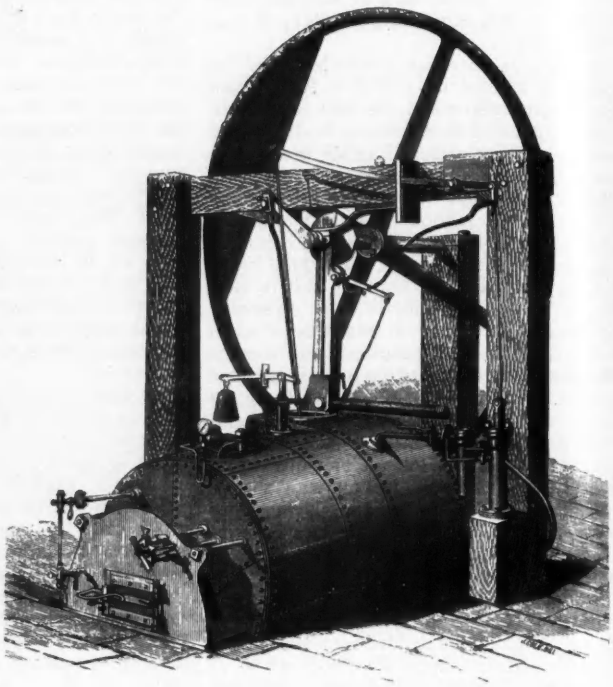
An Introductory Course in College Physics. Fourth edition. By Newton H. Black and E. P. Little. The Macmillan Company, 10, South Audley Street, London, W.1. Price 47s.

Resistance Welding Theory and Use. Prepared by Resistance Welding Committee, American Welding Society. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 36s.

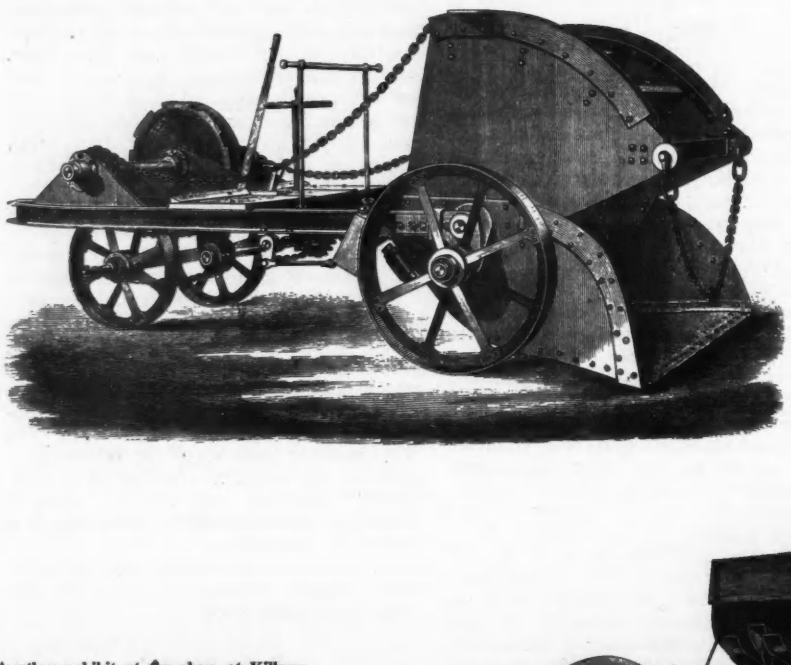
Engineering Dynamics, Vol. II (Elastic Problems of Single Machine Elements). By C. B. Biezeno and R. Grammel. Blackie and Sons, Ltd., 17, Stanhope Street, Glasgow, C.4. Price 90s.

ENGRAVINGS OF 1879

Below, there is reproduced, from our issue of May 9, 1879, an engraving showing a folding canoe which was designed by the Rev. E. L. Berthon "on much the same principle as his well-known collapsing boats." When folded, it was "but 3in thick," and with all its fittings weighed no more than 40 lb, so that one man, we stated, could "carry it with ease under his arm." Our description adds: "the mechanical details have been very nicely worked out, and the result is a portable boat capable of carrying about 16 stones with perfect safety."

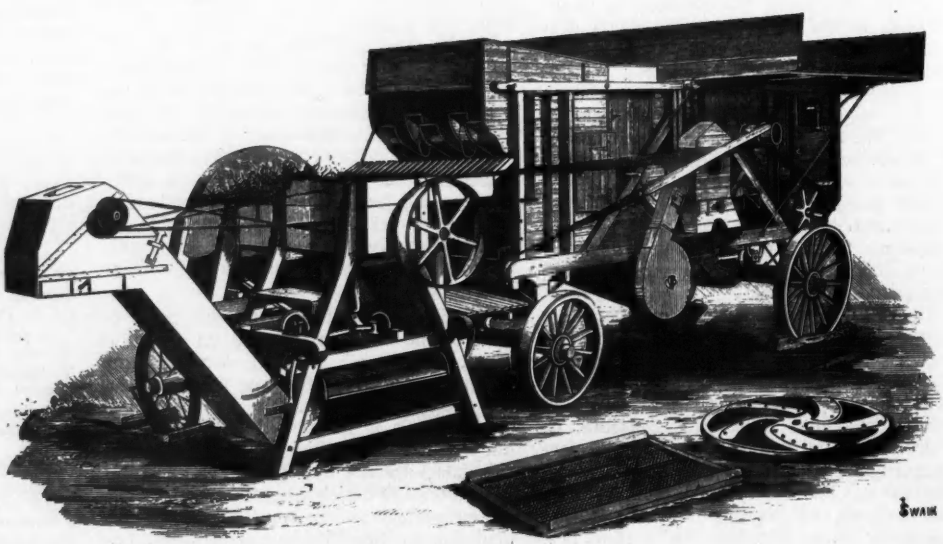


In our issue of June 20, 1879, there was published an account of the historical exhibits at the Royal Agricultural Society's show at Kilburn. Those exhibits included a Trevithick engine of 1811, an engraving of which is reproduced above. This engine was believed to have been used for driving a thresher. To all intents and purposes, our description says, "it is a Leupold engine, high-pressure steam being admitted below the piston, and forcing it up against the pressure of the air and the resistance to be overcome."



The left-hand engraving illustrates a steam scoop, which was produced by John Fowler, of Leeds, and exhibited at the Royal Show mentioned above. A description in our issue of June 27, 1879, says: "two 16-horse power engines are employed to operate the scoop, which when fairly full holds two and a-half cubic yards of earth."

Another exhibit at the show at Kilburn was the combined thresher and chaff cutter, illustrated by the right-hand engraving. It was built by Clayton and Shuttleworth, and mentioned briefly in our issue of June 27, 1879. It seems likely that this was one of the first examples of a chaff cutter arranged to take its drive from the thresher. Normally, of course, chaff cutting was a separate operation. The arrangement whereby the chaff cutter and thresher operated in tandem was devised, our article says, for the benefit of "those countries wherein chopped straw is used for fodder."



Public Works Plant

Some of the exhibits at the recent Public Works Exhibition, at Olympia, are described in this article. No attempt has been made to give a comprehensive review of the exhibition ; we have simply selected from the multitude of exhibits one or two which are new products or which exemplify contemporary trends.

LAST week the Public Works and Municipal Services Congress and Exhibition was held in London, at Olympia. At the congress thirty-three papers were discussed, on subjects such as town planning and architecture, and various aspects of municipal affairs, particularly on the engineering side. Papers more especially devoted to engineering matters included a group of papers from the Road Research Laboratory on control and testing in road construction, and on skidding, "before and after" studies, and road layouts, all related to road accidents. There were also papers on sewage purification —one on the nature of sedimentation and another on a study of dissolved oxygen in the Thames estuary—and on topics such as the running of a County vehicle depot, on street lighting, and public cleansing. Technical sessions at which these papers were discussed were held while the exhibition was in progress.

The display of plant, and of exhibits from industries connected with public and municipal works, such as quarrying organisations, and the D.S.I.R., were exceptionally comprehensive. The exhibition was larger than its predecessors, thus reflecting the increasing importance of mechanical equipment in this field. One noticeable trend was towards larger and more powerful machines. But small, labour-saving devices for all sorts of duties were also in evidence. Much of the plant to be seen was, however, of standard design, or incorporating only minor modifications to well-tried models. Our description of the exhibits is, therefore, confined to a few examples of special interest, which have not been described before in these columns. This selection, however, is not intended to be representative of the exhibition as a whole, and it should be borne in mind that a very complete exhibition of the plant available for public works and for municipal duties was to be seen at Olympia last week.

Cement and Concrete Plant

Bulk handling of cement, generally in combination with weigh-batching plant for concrete-making, is becoming increasingly common, even on constructional sites of comparatively small size. A number of manufacturers have been active in providing plant of this kind, including Eonlt Engineering Company, Ltd., Slade Green, Erith, Kent. This firm showed a cement silo of 12 tons capacity, intended to give the simplicity essential for the use of bulk cement on the small site. The silo is 6ft in diameter, and has a height of 22ft 3in. Cement is delivered to it at the top, through a 4in supply pipe, with a dust arrester at the silo coupling. Extraction of the cement in measured batches is achieved by simple manually-operated controls. A "dispenser"—that is, a measuring box, at the bottom of the silo—can be filled from the silo by lifting a control lever; depression of the lever empties the measured batch of ¼ cwt from the dispenser. Arching at the base of the cylinder is overcome by a small air cylinder, linked to the dispenser lever so that it aerates the cement when the lever is raised.

A more elaborate power-operated plant with cement storage of 14 tons and weigh-batching for the cement was also exhibited by the same firm. The main storage silo of this plant holds 10 tons of cement, and a further 4 tons can be accommodated in a feed-hopper, situated at a convenient height to receive loads of cement from a tipping lorry. Cement in this hopper is activated by low-pressure compressed air, and is elevated to the silo by a screw conveyor. Because of the aeration, the hopper is shallow, with almost a flat bottom, so it can be installed at ground level ; thus, no special foundations need by prepared when this plant is installed.

The cement weigh-batcher will measure out quantities up to 400 lb, an accuracy of ±2 lb being claimed. It is cantilevered out from the steel frame of the plant at a level near the top of the silo, in a position convenient for delivery into a chute. Cement is fed into the weigh-hopper from an air conveyor, which starts at the top of the screw conveyor. There are two other air conveyors at the base of the silo. The cement is kept aerated, and is fed into the weigh-batcher through the screw conveyor, which has a capacity of 25 tons per hour. The feed hopper and screw conveyor each have a 5 h.p. electric motor, and two motors of 1 h.p., and one of ½ h.p. are installed for the air conveyors. The plant is stated to be virtually automatic in operation.

Apart from bulk-cement handling and weigh-batching, another aspect of the increasing importance given to quality control and mechanisation in concrete making is that of ready-mixed concrete, supplied to the site in truck-mounted agitators. The largest of the agitator/mixer trucks, which are all intended primarily for the delivery of ready-mixed concrete, is the one manufactured by Stothert and Pitt, Ltd., of Bath. This machine has a capacity of 6 cubic yards when used as an agitator, and 4½ cubic yards as a mixer. The mixer unit is of American design, manufactured in this country, and is built on a steel frame which is mounted on a six-wheeled chassis. A Ford engine mounted on the frame drives the mixer ; all the controls are on one side of the unit. The drum is emptied by rotating it in the reverse direction from that used for mixing and agitating.

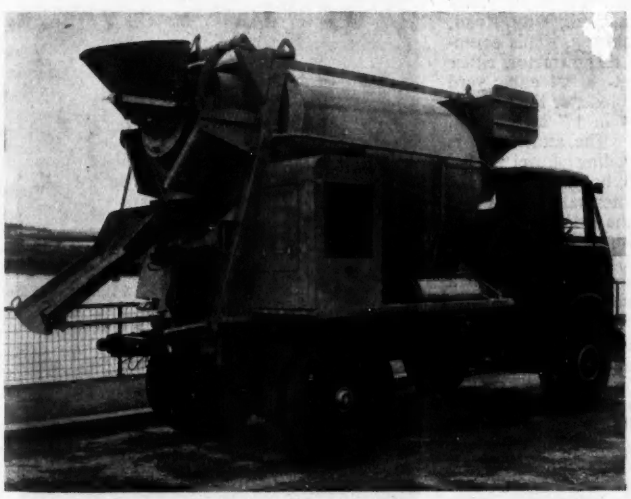
Another example of this class of equipment is

Hydraulic loading shovel with high discharge height

the Rex 3½ cubic yard "Adjusta-Wate Moto-mixer," illustrated herewith, and made by Blaw Knox, Ltd., 90/94, Brompton Road, London, S.W.3. Its design has aimed at adjusting the centre of gravity of the combined truck and mixer to give a good load distribution, and a four-wheeled chassis is employed ; attention has also been paid to rapidity of charging, mixing and discharge. When the drum is fitted with a sealed hopper, as shown in the illustration, or has a door to close it, the capacities are increased to 4 cubic yards as a mixer, and 5 cubic yards as an agitator. The drum can be filled through the sealed hopper, or, if this device is not fitted, through a hatch in the top of the drum. The drum has recirculating blades which give an additional end-to-end mixing action as the drum revolves. The power unit of the mixer is a Perkins three-cylinder diesel engine which develops 30 b.h.p. at 2250 r.p.m. The drum rotates at 11 r.p.m. when mixing, and 5 r.p.m. when agitating, but its speed can be increased up to 13 r.p.m. for discharging.

Tractor-Mounted Loaders and Excavators

Excavators and earth-moving plant were, of course, very much to the fore at the exhibition,



(Left) Truck-mounted concrete mixing plant, with a maximum capacity of 4 cubic yards when used as a mixer, and 5 cubic yards when used as an agitator. (Right) 10 cubic yard dumper with six-wheeled drive and ten road speeds. The hydraulic tipping gear raises the body to an angle of 70 deg. in twelve to fifteen seconds and returns it in twenty seconds

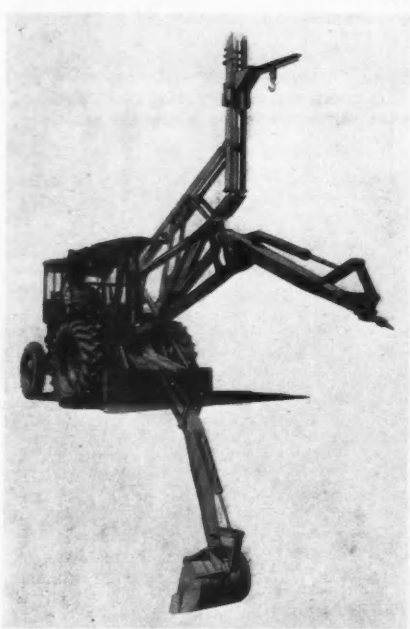
Demonstration of the combined loading and clamshell shovel of the "4 in 1" tractor-mounted equipment

and many improvements in detail have been incorporated in well-known makes of this class of plant. Here we give one or two examples of lighter, tractor-mounted equipment, particularly loaders, amongst which several new models were shown.

The 2HHCR "Hi-Tip" hydraulic loading shovel manufactured by F. E. Weatherill, Ltd., of Welwyn Garden City, can discharge its load into hoppers or receptacles slightly above 16ft in height; the machine loads with a scoop crowd action, for which a higher hourly output than with earlier models is claimed. The discharge height is clearly shown in the illustration of the machine. It is powered by the Fordson "Major" four-cylinder diesel engine, developing 44 b.h.p. at 1800 r.p.m. Lifting capacity is given as 15 cwt, and the lifting and lowering times are five to six seconds and four to five seconds respectively. The machine needs a headroom of 8ft 4in when the bucket is lowered.

A hydraulic loader of ¾ cubic yard (1 ton) capacity, known as the "Cardinal," has been introduced by E. Boydell and Co., Ltd., Old Trafford, Manchester, 16. The machine has a driver-controlled bucket action at the loading position, with an automatic crowding and levelling action which first levels the bucket and then maintains it in a level position up to its maximum lift. Maximum tipping height, achieved in seven and a half seconds with a fully loaded bucket, is 9ft 5in to bucket lip (with 17in forward reach and 50 deg. tipping angle). Maximum forward reach is 4ft 5in. The "Cardinal" is powered by a four-cylinder Fordson "Major" diesel engine, developing 44 b.h.p. at 1750 r.p.m., with a maximum torque of 140 lb per foot at 1100 r.p.m., through an 11in single dry plate clutch. The constant-mesh gearbox provides six forward and two reverse speeds.

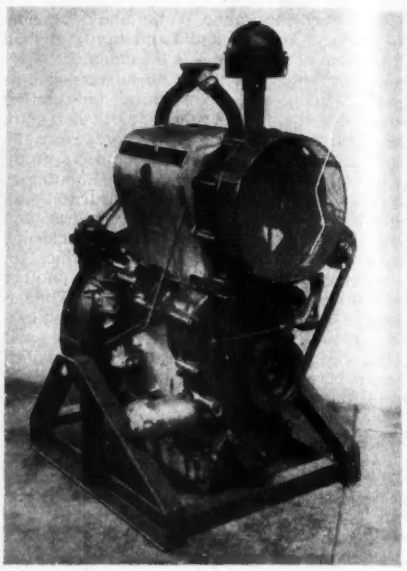
An overshot loader of American design is now being manufactured in this country by David Brown Industries, Ltd., Hanworth Park, Feltham, Middlesex. The machine is essentially simple in operation, the bucket being raised by a hydraulic ram on each side of the tractor, and tipped by two smaller rams acting directly against the bucket. "Straight-line" loading cycles can be carried out with this machine in twenty-eight seconds, lifting and lowering times being respectively twelve and four seconds. The bucket is 5ft 10in wide, and its rated capacity is 1 cubic yard, and the rear discharge height is 7ft 3in. A maximum brake horsepower of 50 is developed by the machine's David Brown engine, at 1800 r.p.m. The loader is illustrated below.



This composite illustration shows three alternative attachments which can be fitted to the "Mantis" tractor for various duties

Another American design is the so-called skid-shovel, which the International Harvester Company of Great Britain, Ltd., City Road, London, E.C.1, is manufacturing. This equipment can be used with a B.T.D.6 tractor, either with a 1½ cubic yard bucket or a 1 cubic yard heavy-duty bucket, a dozer blade, or the maker's hydraulically controlled "4 in 1" attachment, which we illustrate above. The attachment is basically a digging and loading shovel; it is shown in use as a clamshell, holding a length of pipe. In addition to the normal digging and clamshell digging actions, the "4 in 1" attachment, it is affirmed, can also be used as a bulldozer, and what is termed a "bullclam," this last action being "somewhere between that of a bulldozer and a push scraper."

A versatile item of plant in the range of light tractor-mounted tools has been developed by Mathew Brothers, Ltd., Wallington, Surrey, and is known as the "Mantis." A wheeled tractor powered by a 40 h.p. "Fordson Major" diesel engine has a hydraulically operated, braced boom, at the end of which several different kinds of attachments can be fitted, as shown by the composite illustration herewith. The lower position of the boom shown in this illustration has a drag shovel, or back-acter, as it is sometimes called, fitted for excavating trenches and similar work; a trench 12ft deep can be excavated. The central position of the boom shows a compressed air tool (operated from a built-in compressor), which can be used for drilling holes, concrete breaking, and so forth; this attachment can operate to a height of 17ft. The upper position of the boom shows the attachment used as a crane; the maximum load

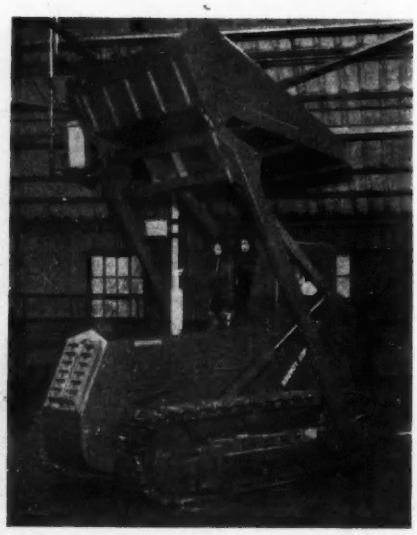


Two-cylinder, four-stroke diesel engine. The engine is air cooled and develops 13 b.h.p.

which can be lifted is 1120 lb, and the maximum height of lift is 28ft to the crane hook. A variant of this last use was shown at the exhibition, and consisted of a platform for overhead working fixed on the guides of the crane attachment. The illustration also shows the small bulldozer blade which can be fitted to the machine. The main boom and its working attachment form, in effect, a half-circle machine; thus loads can also be carried at the side of the tractor—for instance, as a side-lift fork lift truck. All controls are at the driving position, and the maximum travelling speed is 15 m.p.h.

Small Air-Cooled Diesel Engines

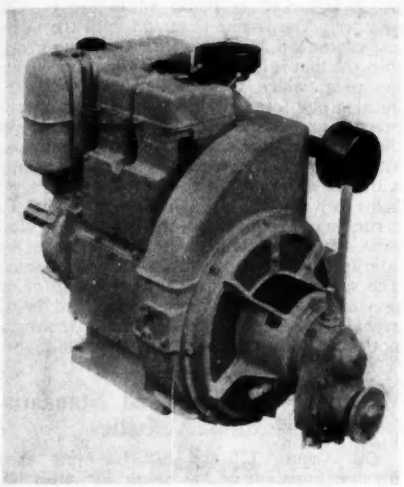
Air-cooled diesel engines in the smaller horsepower ranges have many applications in stationary and mobile equipments, and a recently introduced engine in this class is the "2D" engine of David Brown Industries, Ltd., illustrated above. This air-cooled two-cylinder four-stroke



Overshot loader with a bucket of 1 cubic yard capacity

engine develops up to 13 b.h.p. at 1800 r.p.m. and has a 3½in bore with a 4in stroke. It has separate cast iron cylinder barrels in an aluminium alloy cylinder block and the crankcase and sump are also of light alloy construction. The aluminium alloy cylinder head is fitted with replaceable valve seat inserts and the inlet ports are of tangential design to impart swirl. C.A.V. fuel injection equipment is fitted and a mechanical governor operates throughout the entire speed range, which under full load is from 800 to 1800 r.p.m. with a low idling speed of 500 r.p.m.

Another small air-cooled four-stroke diesel engine was exhibited by R. A. Lister and Co., Ltd. It developes from 3 h.p. at 750 r.p.m. to 7 h.p. at 1800 r.p.m. Its two cylinders have a bore of 3in and a stroke of 3½in. A direct injection combustion chamber is situated in the crown of each piston and this closed toroidal chamber is used with a pintle fuel injector nozzle with a single large hole. The cylinders, cylinder heads and injector sleeves



7 h.p. air-cooled, two-cylinder diesel engine

are formed to give efficient heat dissipation and cooling air is driven over them by a large flywheel fan through a cowling, as can be seen in the illustration of the engine on this page.

A 2¼-gallon fuel tank is mounted on the engine and fuel is gravity fed to a C.A.V. fuel pump and injector, which are totally enclosed. A centrifugal governor mounted on the crankshaft is stated to give less than 4 per cent steady variation when the load is on or off the engine.

Heavy Dumpers

During recent years there has been a steady demand for very large capacity dumpers capable of relatively high travelling speeds, for use in contracts involving the removal of earth and other materials in bulk over appreciable distances. Four examples of these heavy vehicles were shown at Olympia : a "Euclid" 16 cubic yards machine, an A.E.C. 10 cubic yards machine, a "Foden" 10 cubic yards machine, and a "Scammell" 8 cubic yards capacity machine.

The A.E.C. 10 cubic yards "Dumptruk," illustrated on page 737, is a six-wheel drive machine, the driven front axle of which can be engaged or disengaged in accordance with the operating conditions. It can also be supplied with a non-driven front axle if required. The vehicle is fitted with an A.E.C. 11·3-litre oil engine developing 150 b.h.p. at 1800 r.p.m., and power is transmitted through a five-speed main gearbox and a two-speed constant-mesh auxiliary box to give ten forward and two reverse speeds. The two-speed auxiliary gearbox incorporates the gears for the transfer of the drive to the front axle, and a power take-off fitted on the top of the main gearbox drives the hydraulic pump of the tipping gear. Air pressure braking is fitted and the worm and nut steering gear is provided with hydraulic power assistance.

The massive pressed steel frame has 14in deep channel section side members, reinforced by a full depth angle-section internal flitch. Built into the frame is an "Edbro" dump gear for the 10 cubic yards capacity dumper body, which incorporates a protective canopy for the driver's cab and a rear end gate. The triple extension twin hydraulic rams used for dumping purposes are supplied by a twelve-cylinder swashplate plunger pump with an output of 40 g.p.m. and a maximum working pressure of 1500 lb per square inch. This equipment is designed to tip the body to an angle of 70 deg. in twelve to fifteen seconds and return it in twenty seconds.

The 8 cubic yards "Mountaineer" dump truck of Scammell Lorries, Ltd., is built as a medium capacity end tipping vehicle for work in quarries, open cast mines, and public works sites. It can be supplied with alternative diesel engine drives and power is transmitted through a six-speed gearbox to both axles. The front axle drive can be disengaged when not required.

The welded steel body of the vehicle is tilted by a pair of hydraulic rams, to which pressure fluid is supplied by a "Deri-Sine" pump driven by a gearbox power take-off through a propeller shaft. It has a very high angle and speed of tip, the twin hydraulic rams raising it to a 72 deg. angle in sixteen seconds.

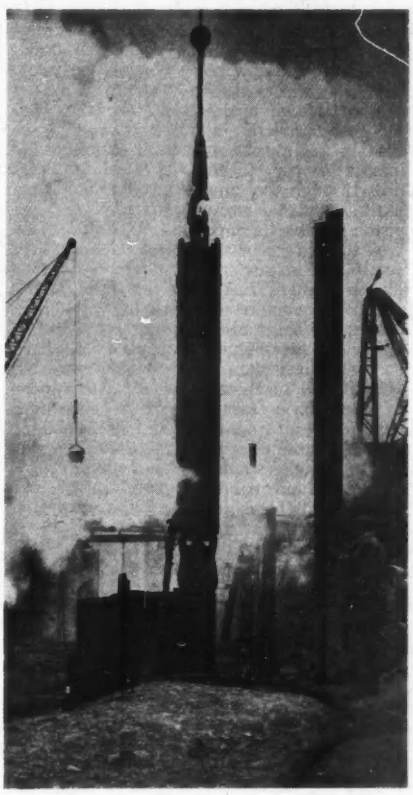
The pressed steel cab can be offset to either side to suit the control position, and steering is power assisted. To reduce fatigue when operating under adverse conditions steering dampers are fitted to prevent shocks being transmitted to the steering wheel.

Other Plant and Equipment

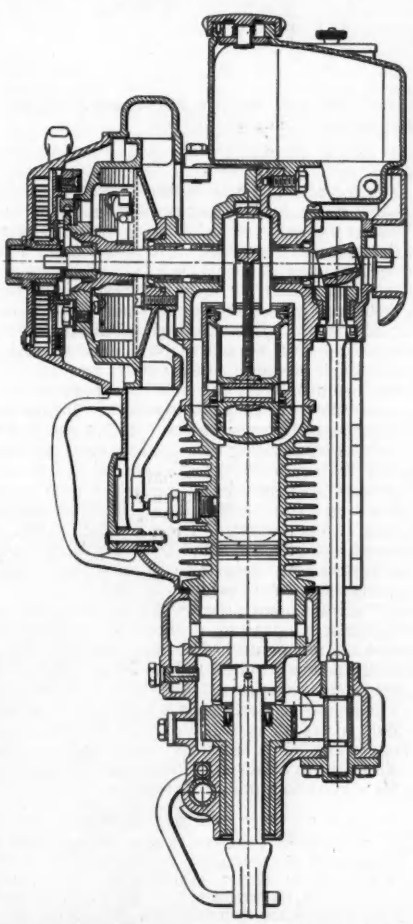
An increase in the use of plastics was noticeable at the exhibition. This trend was exemplified by several firms, including Microcell Ltd., 56, Kingsway, London, W.C.2., whose exhibits included water tanks constructed from glass-reinforced plastic panels. The advantages claimed for this innovation include a weight of about one-third of that for the counterpart in mild steel. Each panel is flanged for jointing, and has a cruciform corrugation for strengthening it ; when a tank is assembled inclined ties are fastened inside it between the base and the junction between each pair of side panels at the top of the tank.

A new range of self-priming contractors' pumps was exhibited by Sigmund Pumps, Ltd., Team Valley, Gateshead-on-Tyne, 11, under the name "PortaPak." The range includes petrol and diesel-engine-driven sets up to 3in pump size.

The 1½in pump (the smallest) weighs only 43 lb and has an output of up to 3750 g.p.h.



Pile extractor capable of delivering 120 blows per minute, shown pulling a 65ft steel sheet pile



General arrangement of petrol-engine-driven rock drill. The engine piston and an impact piston move in a common cylinder and at the end of each working stroke the impact piston is returned to its upper position in the cylinder by air compressed in a chamber behind the engine piston

with heads up to 63ft. The 2in, with a total weight of 85 lb, handles up to 5500 g.p.h., and will give heads up to 85ft. The 3in delivers up to 15,000 g.p.h. and operates against heads up to 105ft. Sledge mounting is standard for all three sizes, but a two-wheeled trolley is available for the 3in pump. Aluminium alloy is employed for the main castings and all the "PortaPak" units are fitted with grease-lubricated, double-mechanical seal.

For many years Atlas Copco (Great Britain), Ltd., has manufactured rock drills driven by compressed air, and the firm has now developed a light portable petrol-engine-driven drill for use on sites where a supply of compressed air is not available and where it would be difficult or uneconomic to take an air compressor. This new drill is largely of light alloy construction, and as it weighs only 53 lb it can be readily transported over rough, difficult terrain on a man's back using a special "pack" frame. The construction of the drill can be seen in the drawing.

The conventional, single-cylinder, two-stroke petrol engine of 1 h.p. is built into the head of the machine with the crankcase uppermost. This engine has a flywheel magneto and a floatless carburetter, and it is started by a spring-return pull wire fitted in front of the flywheel. It runs at 2300 r.p.m. and its piston operates at the upper end of a cylinder at the lower end of which there is a freely moving hammer-impact piston. Both of these pistons are made with a flange of much

larger diameter at their rear ends, and these flanges form secondary pistons working in enlarged chambers at the top and bottom of the main cylinder. The upper part of the engine piston serves to compress air in the enlarged cylinder chamber as the piston reciprocates, and this compressed air is delivered via a duct to below the impact piston.

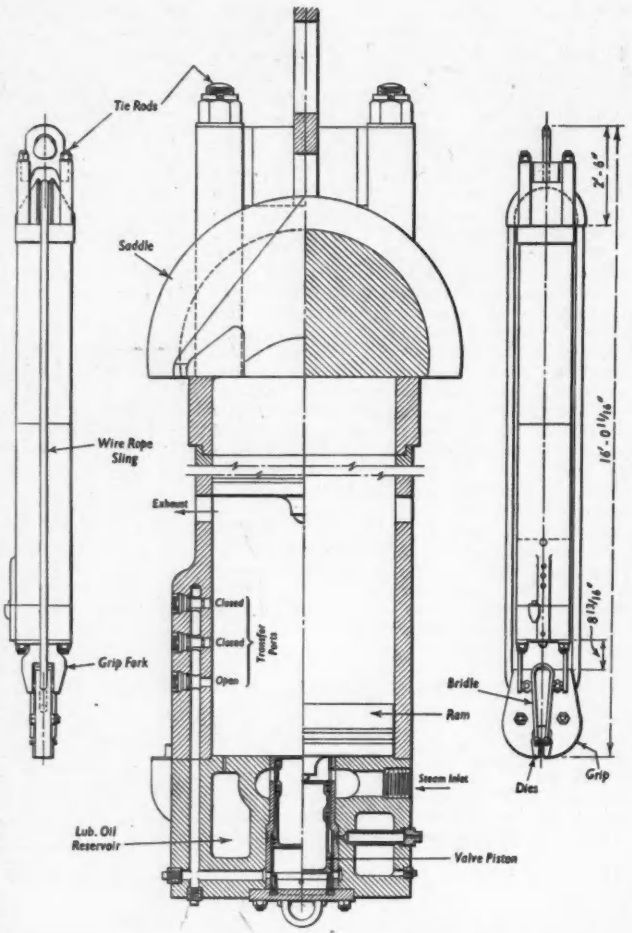
When the two pistons are at their innermost positions and the charge is fired, the engine piston is forced upwards whilst the impact piston is driven down against the compressed air cushion to impart its impact energy to the drill through an anvil block. When the engine piston reaches its upper limit to open the exhaust ports and release the gas pressure in the cylinder, the air pressure pushes the impact piston up ready for the next compression stroke.

Whilst the machine is in operation a feed of compressed air from the impact piston chamber is taken through a reduction nozzle and channels in the anvil block and drill steel to the bit. This flow of air blows dust from the hole as the drill penetrates the rock. The drill is rotated during cutting by a ratchet working a toothed wheel on a rotation chuck into which the drill shank fits. Motion to the ratchet is obtained directly from the engine crankshaft through a torsion shaft which moves backwards and forwards through an angle of 30 deg. for each rotation of the crankshaft. Rotation of the chuck is cut off by movement of a small lever which disconnects the ratchet and ratchet wheel. When the rotation mechanism is shut off air pressure in the space below the impact piston is released so that its return force is removed and the piston does not move whilst the engine is running.

The machine is stated to be capable of drilling holes in hard granite at a rate of 6½in per minute, using 1¼in tungsten carbide bits, and up to a maximum depth of 13ft. It can readily be adapted for use as a breaker.

A heavy pile extractor was shown amongst the display on the stand of the British Steel Piling Company, Ltd., Haymarket, London, S.W.1. We illustrate this extractor in the photograph reproduced on page 739 and the accompanying diagram. This extractor is designated the HD.15, and is intended for the heaviest class of work. The extractor is totally enclosed and has only two moving parts, the ram and the valve piston. Upward blows from the ram are transferred to the pile through an endless wire rope sling attached between a saddle at the top head of the extractor and the jaws which grip the pile.

The cycle of operations can be followed from the diagram. Before extraction is started, the ram is at the position shown on the right, where it holds the valve piston in its lower position. Steam is admitted, raising the ram with the full steam pressure behind it, until the open transfer port is reached. At this point the valve piston is raised, thus cutting off the steam supply, and giving expansive working for the rest of the stroke until the exhaust port is uncovered. The ram hits the top head and rebounds downwards; after passing the exhaust port the contents of the cylinder space beneath the ram are compressed.



Arrangement of pile extractor. The cross section is divided and shows the ram and valve piston in different positions

The increase in pressure thus caused holds the valve piston in its upper position until the ram passes the open port. Increasing pressure below the ram then forces the valve piston down, and, hence, initiates the next cycle.

Approximately 120 blows per minute are delivered by the extractor. Their intensity can be controlled by two methods. Another of the three transfer points can be opened to give a greater or less degree of expansive working, and the steam pressure can also be varied, up to a maximum of 150 lb per square inch. The normal pressure is, however, 90 lb to 110 lb per square inch, corresponding to a steam consumption of 2100 lb per hour. The weight of the ram is 3850 lb, and the kinetic energy of each of its blows is up to 12,000ft-lb, at 100 lb per square inch steam pressure. The extractor is 16ft in length and weighs almost 10,000 lb. The jaws will grip steel piles from ⅜in to 1in in thickness, with a minimum "flat" width of 6½in.

The maximum downward reaction when the extractor is operating is about 10 tons, but the makers recommend that a crane capable of giving a steady pull of at least 15 tons should be employed when operating with a 110 lb per square inch boiler. It is pointed out that this pull is not an essential part of the extracting operation, but is necessary so that the wire rope sling does not slacken. The extractor is designed for a maximum pull of 50 tons.

TRANSLUCENT FLEXIBLE DOORS.—A new form of swing door of translucent, flexible material is now being made by Parker, Winder and Achurch, Ltd., Broad Street, Birmingham, 1. These doors are made from a plasticised material based on a copolymer of vinyl chloride and vinyl acetate, and as the whole door panel is translucent the need for observation panels is eliminated. The doors automatically close to centre and can easily be passed through without propping open. They are available in sizes up to 4ft wide by 8ft high, or from 4ft to 6ft wide to 7ft high.

Diesel Engine Starter

A STARTER which is claimed to ensure a rapid start for most diesel engines, up to 250mm bore, in all weather conditions, is being marketed by Storhaven Engineering, Ltd., Essex Place, Newhaven, Sussex. The device, which is simple to operate, is works tested to a pressure of 600 atmospheres and is manufactured in two sizes, for engines having cylinder bores up to 200mm and for those up to 250mm bore, irrespective of the number of cylinders. The "Hansa" starter consists of a pressure cylinder equipped with an automatic valve and a safety valve, and containing a film holder surmounted by a lock and plug. The unit is connected to one of the cylinder heads. The overall length of the tank for each size of starter is respectively 12½in and 16in, the length of the film holder and plug is 7in and 9in, while the valve and holder is common to both sizes and measures 10¼in in length. For starting, a piece of film, varying in length from 4ft 6in for an engine of 110mm bore to 14ft 9in for an engine of 250mm bore, is placed in the film holder, which is locked in place within the pressure cylinder. The engine is turned until the piston just passes top dead centre for the firing stroke, then the film is ignited by a match dropped into the plug, which is immediately closed. The burning film forms gas of high temperature and pressure and after a period of about five seconds the automatic valve opens and the gas flows into the cylinder to force the piston downwards with increasing pressure. Since the gas is hot it helps to warm up the engine. When the engine is running the plug is reopened and a cap placed over the automatic valve opening knob and adjusted tightly to avoid loss of compression. The safety valve located at the bottom of the pressure cylinder provides a safeguard in the event of too much film being used or the engine not being in the correct starting position.

National Research and Standardisation Activities

ON August 17, the Act to bring about an amalgamation of the South African Bureau of Standards and the Council for Scientific and Industrial Research, came into effect. This Act abolishes the existing research and standards councils and provides for a new main council on which the interests of both research and standardisation are represented. The new council is responsible to Parliament through the Minister of Economic Affairs. Over the next few months the administrative sections of the Bureau of Standards will be integrated into the administration of the C.S.I.R. For the time being the national testing laboratories of the Bureau will continue to be operated separately, as well as the national research laboratories of the C.S.I.R. At a later stage certain functions of the research laboratories will probably be transferred to the testing laboratories and vice versa, in order to ensure that the most efficient use is made of the highly-trained scientists and of some very expensive specialised apparatus and machines which may be used for both standardisation and research purposes. The new organisation assumes the Bureau's responsibility for drawing up national safety specifications, codes of practice and industrial quality specifications. It will also administer the S.A.B.S. mark scheme for guaranteeing that industrial products are up to specification, and will control the use of the national hallmarks on objects made of gold and silver. In addition to controlling the eight national research institutes of the C.S.I.R., the new council takes over the allocation of Government funds for the subsidy of research in the universities, medical schools, hospitals and co-operative research institutes supported by industry. In co-operation with the Department of External Affairs, it assumes the C.S.I.R.'s responsibility for maintaining scientific relations with foreign countries, and takes over the running of the scientific liaison offices in London and Washington. In the ten years since the establishment of the S.A. Bureau of Standards, that body has done much to remove the prejudice against South African-made goods and to promote South Africa's export trade.

Aeronautical Development in Australia

BY L. P. COOMBES, D.F.C., B.Sc., F.I.A.S., F.C.G.I., F.R.Ae.S.

The twelfth British Commonwealth and Empire Lecture was delivered to the Royal Aeronautical Society last night, on the subject of "Aeronautical Development in Australia and its Potential Value to the British Commonwealth." We reproduce the parts of the address dealing with research on chromium alloys and combustion stability and flame-out.

I SHOULD like to describe two researches in the field of gas turbines. The first is metallurgical in character. The continuing requirement for higher operating temperatures in the aircraft gas turbine has been met, over the past fifteen years or so, by spectacular advances in the high temperature strength of commercially available alloys. Improvements to these alloys continue to be made and, for example, Nimonic 100 has recently been developed and shown considerable improvements over its justly famous predecessors. All established alloys in use, however, are based on one or other of the three related metals, iron, nickel and cobalt, and since

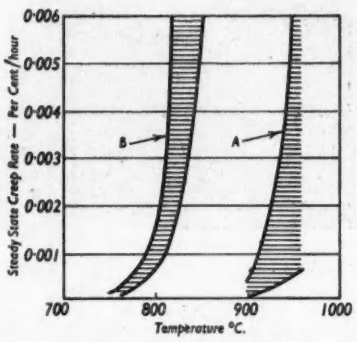


Fig. 1—Comparative creep rates of chromium alloys (*A*), and strong commercial alloys (*B*) at 12 tons per square inch

the desired operating temperatures have already risen to within a few hundred degrees of their melting points, it is evident that, if operating temperatures are to be pushed substantially higher without forced cooling of the turbine blades, the present alloys will not be satisfactory.

Recognition of this situation has resulted in a considerable volume of laboratory research on higher-melting materials in various parts of the world. At the Aeronautical Research Laboratories a comprehensive review was made some years ago and, on both theoretical and practical grounds, chromium was chosen as a promising basis on which to develop new heat-resistant alloys. Among its more obvious advantages, chromium has a melting point more than 300 deg. higher than that of iron, its density is some 12 per cent less, and it is capable of forming a surface film which is highly resistant to oxidation. Also, both world and Australian resources of chromium ore are good, although the latter are as yet largely undeveloped.

When the A.R.L. project was begun, little was known of chromium-based alloys in general and thus the early work was necessarily concerned with constitutional studies of the alloys of chromium with such solute metals as beryllium, titanium, tungsten, and zirconium. The refractory nature of these alloys meant that special experimental techniques had to be developed, including pyrometry, and methods of crucible preparation. The investigation of chromium production by electrolytic methods was also started at an early stage and has continued up to the present time. Over this period there has been a steady improvement in the quality of the product, the current "standard" grade containing 0·01 per cent oxygen, 0·002 per cent nitrogen and practically no metallic impurities. Work is now aimed at improving the economics of chromium production by substantially increasing the efficiency of the electrolytic process.

Since 1954, increasing emphasis has been placed on developing alloys and determining properties appropriate to the turbine blade application. Thus, work is being done on creep resistance in the range 900 deg. to 1000 deg. Cent. (using in the first instance compression creep testing machines), hot hardness, scaling and surface protection, and methods of forming the alloys into the required shapes.

While it is not possible to present comprehensive creep data in a single diagram, Fig. 1 illustrates the comparative creep performance of high-grade commercial materials, and some A.R.L. chromium alloys are capable of showing comparable creep resistance at temperatures 100 deg. to 200 deg. Cent. higher. If the test temperature for the commercial alloys is raised to 950 deg. Cent., they exhibit minimum creep rates ten to 100 times faster than do the experimental materials, and thus fail much sooner.

Attempts have been made to shape some of the stronger chromium alloys by modifications of commercial techniques. Considerable success has been achieved in hot-working the alloys, and machining and grinding do not appear to present any insuperable obstacles. On the other hand, it seems that melting and casting are always likely to require special equipment and techniques (e.g. argon-arc furnaces, now in semi-commercial use in U.S.A. for producing molybdenum).

Much remains to be done before the alloys can be regarded as fully evaluated. To this end, thermal shock, tensile creep and hot fatigue tests are projected in the near future, followed by tests in an experimental turbine rig.

Another important property being investigated is the ductility of chromium alloys at ordinary temperatures. It is desirable that any high-duty engineering material should show a certain minimum of ductility. Work at A.R.L. over the past three years has resulted in pure chromium being produced for the first time in a form which is ductile at room temperature. Furthermore, the extent of the ductility is of engineering significance: for example, values of 20 per cent elongation in a room-temperature tensile test have been obtained. Fig. 2 shows examples of ductile chromium.

An evaluation has been made of the factors governing the ductility of chromium. They fall into three main categories: (*a*) purity; (*b*) surface condition, and (*c*) metallurgical structure. Of these, the most important would appear to be purity and it has been shown that extremely small amounts of nitrogen (0·02 per cent or less) present in solution, can have a catastrophic effect. The effect of N_2 on the temperature at which the ductile-to-brittle transition occurs is shown in Fig. 3.

The foregoing work has been a necessary preliminary to the main problem of ductility in useful chromium-base alloys. Dilute chromium-base alloys have already been produced which are ductile at room temperature, and this has been achieved by making use of the techniques developed for pure chromium. There is every confidence that similar success will be obtained with the more highly alloyed materials.

I come now to the second turbine investigation. The Australian team which was sent to the U.K. during the war to assist in the development of jet engines, brought back an interest in combustion research. One of the members felt that the cut-and-try approach to combustor design could be improved.

The various zones of a combustion chamber which are separated by baffles, colanders and orifices of various sorts, connect with one another so closely that a variation in one air flow affects all the others. Thus, it is extremely difficult to separate out the effect of any one parameter. We therefore built what is known as the multi-air supply rig, in which the air flows to the different sectors of a combustion chamber are separately controlled and metered so that any one may be varied without affecting all the others. This has given a detailed insight into the general effects of flow variations, but the most valuable result has been the demonstration of the importance of air flow conditions very close to the fuel spray nozzle. It is in this region that a "pilot flame" is maintained, and changes in the distribution and direction of fuel and air flows can have large effects on the general stability and efficiency of combustion. Air is normally fed through a shroud around the nose of the fuel nozzle for the dual purpose of cooling and elimination of carbon deposits on the front of the atomiser; this small air flow which intimately mixes with the fuel spray was found to have a predominant effect on the placement of fuel within the combustor, and hence on the nature of combustion. It was found that alteration of the momentum or direction of this air flow could cause a change from a fully developed flame of high efficiency and intensity

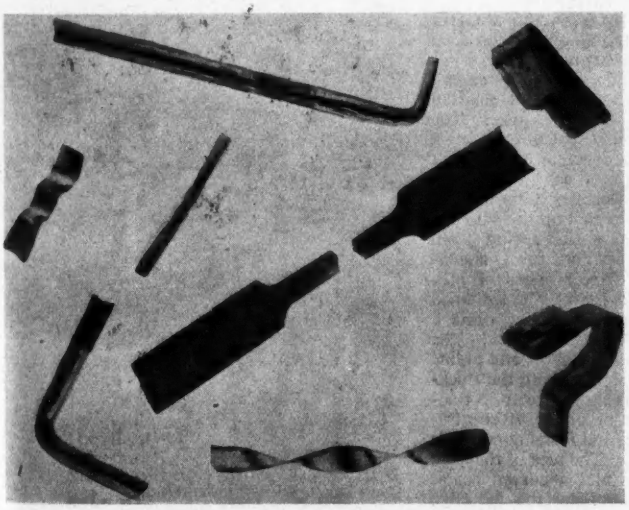


Fig. 2—Examples of ductile chromium

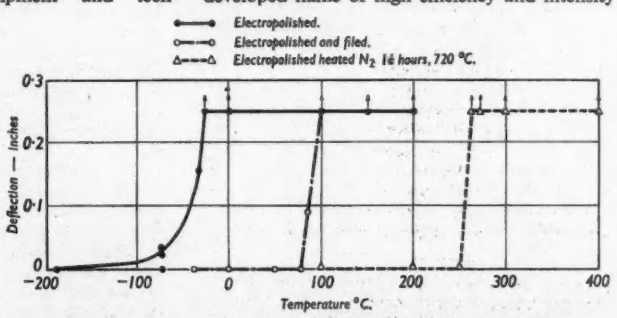


Fig. 3—Effect of various factors on ductile/brittle transitions of chromium

to a core-shaped flame of low efficiency, but of great stability. The region between the two regimes was characterised by unstable transitions between the two modes of combustion, and this was found to be one cause of combustion "rumble." This work was taken up by one engine firm who were able to "tailor" the characteristics of shroud geometry and fuel nozzle characteristics to give the desired high intensity, high efficiency combustion without rumble at cruising revolutions per minute conditions, while retaining the high stability type of flame at lower speeds.

The conditions close to the fuel atomiser had been shown to have such a vital effect on combustion stability that attention was given to their effect on the urgent problem of flame-out of engines at altitude. Some improvement of combustor characteristics was attained by alteration of shroud geometry, but the most dramatic results were obtained when pure oxygen was injected into the primary zone, as shown in Fig. 4; in this way the weak extinction limits were extended tenfold while rich extinction, which can occur during a compressor surge, was virtually suppressed. These results have been attained both in atmospheric pressure rig tests and at simulated altitudes of 40,000ft. The

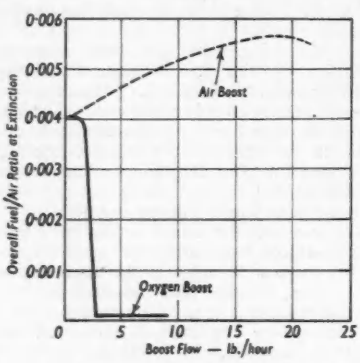


Fig. 4—Variation of extinction limit of typical combustor with oxygen and air boost

oxygen flows necessary to produce this result are so small that it is quite feasible to supply oxygen continuously to an engine during flight. The implications of these results are so important that we are arranging to make flight tests of an engine equipped for continuous oxygen injection.

Continuous oxygen injection may have important applications in the design of new engines. The volume of a combustion chamber is governed by altitude conditions, where the rate at which chemical combination of fuel and oxygen can occur is the controlling process. Thus, by enriching the air with oxygen a desirable reduction in size of the combustion chambers can be achieved. A theoretical study has shown that substantial reductions in engine frontal area for a given thrust can be made in this way. There is even a small reduction in weight in spite of the fact that oxygen and associated storage and control equipment must be carried.

The ignition of combustion systems at altitude is also an important problem and the results of the investigations I have just mentioned have been applied to the design of a new type of igniter, which has been provisionally patented. In this igniter the spark is formed close to the most stable region of combustion by an annular discharge gap surrounding the main fuel nozzle and shroud. The use of low tension, high energy discharge is expected to preclude any trouble due to carbon deposits. Preliminary tests indicate that this device should give ignition right up to the extinction limits of the combustor and is particularly effective where continuous oxygen injection is practised. Very stable propagation of the flame is obtained when the fuel flow is turned up after initial ignition. An experimental unit, interchangeable with a standard atomiser, is being tested at present.

GAS IN INDUSTRY.—It is stated that every phase of the application of gas in industry is to be displayed at an exhibition at the Royal Horticultural Hall, London, from January 22 to February 2, 1957.

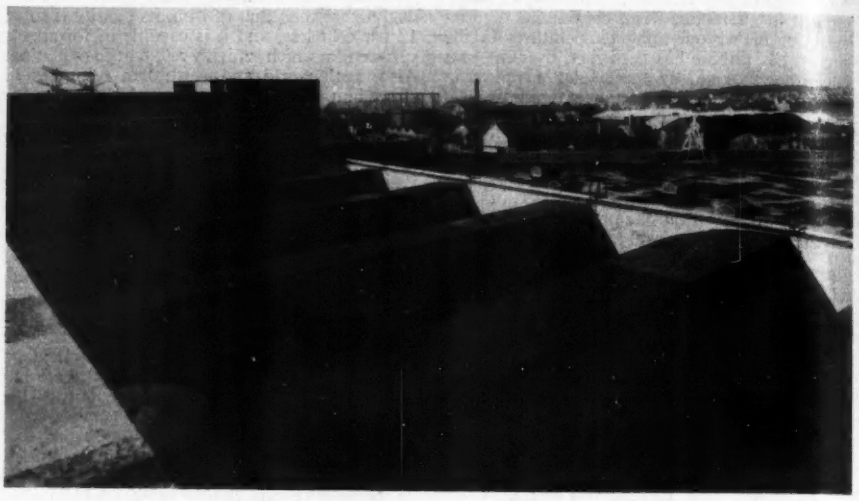
Blending and Bottling Plant

RECENTLY the new blending and bottling premises of John Walker and Sons, Ltd., which occupy a 7-acre site, were opened at Kilmarnock: the plant installed processes single whiskies by blending, marrying and bottling.

The buildings include a duty-free warehouse and blending annexe, bottling hall and materials store, cooperage and workshops, duty-paid warehouse and bond offices, and boiler house. Both the duty-free warehouse and the blending annexe are of reinforced concrete, the former being of flat slab and splay head column design, and the latter of beam and slab. The warehouse provides storage for 1,400,000 gallons of whisky on five floors, each of 3300 square yards, while the annexe, which is of equal height, has only two floors. A conveyor bridge at fourth floor level links the "disgorging" area in the annexe with the casking draining area of the cooperage. Concrete piles cast *in situ* support the vat foundations and the columns, of which the internal units are rectangular, while the outside units have tie beams at the floor edge to carry the 14in solid brick fabric. The floors, which have a granolithic surface, have a loading of 3 cwt per square foot, and the flat slabs are 9in thick with drop panels at the column caps. Accrington red engineering brick is used for the facing with a blue brick dado. Steel-framed windows having close-pitched mullions are fitted. The reinforced concrete bridge has a span of 60ft and a width of 9ft inside the main beams which form the side walls and are 11in thick and 10ft deep at supports, and 8ft 9in deep over the centre third of the span.

Four independent structures linked by expansion joints form the bottling hall and material store and are carried on concrete piles. The bottling hall is a single-storey structure having a post-tensioned prestressed concrete barrel vault roof, illustrated herewith, with north light glazing and a clear floor measuring 176ft long by 108ft wide. The roof is stressed on the Magnel-Blaton system: the five shells spring from edge beams 14ft 6in above floor level, rise to 31ft 9in at the apex and have a chord of 36ft, while the horizontal span is 108ft. The L-shaped interior edge beams have a 6ft deep rib and a 2ft 9in wide flange, both being 8in thick. The shell is 7½in thick at points of support and in line of the prestressing cables; elsewhere the thickness is 3in and the apex is supported from reinforced concrete columns at about 7ft centres standing on the edge beam and forming mullions for the north light glazing. The toes of the edge beam form valley gutters and a curved beam, 2ft 6in deep by 9in thick, stiffens the end edge of each shell, which is supported at the four corners by concrete columns 18in thick and tapering from 2ft 9in in width to 21in at the base. Three high-tensile cables, each of sixteen wires, are located in the upper edge of the shell, while at the bottom three similar cables run in parabolic curves. One cable of forty-eight wires is in the heel of the L-shaped edge beam and a second cable following a parabolic curve is located in the vertical leg.

Bitumen impregnated and coated canvas is laid direct on the external surface of the shell, while the inner surface has a two-coat vermiculate asbestos spray applied to give an anti-condensation paint finish. The floor of the bottling hall is laid with terazzo flooring and the walls are tiled to a height of 6ft.



Barrel vault roofing over bottling hall

The designed floor loading of the material store, bottle washing and whisky disgorging sections, which are of beam and slab construction, varies from 2½ cwt to 3 cwt per square foot. In the bottle washing house the beams, 36in deep by 47ft span, support a 4in concrete roof slab and there is a steel trussed lantern light, 22ft wide, which extends over the length of the compartment.

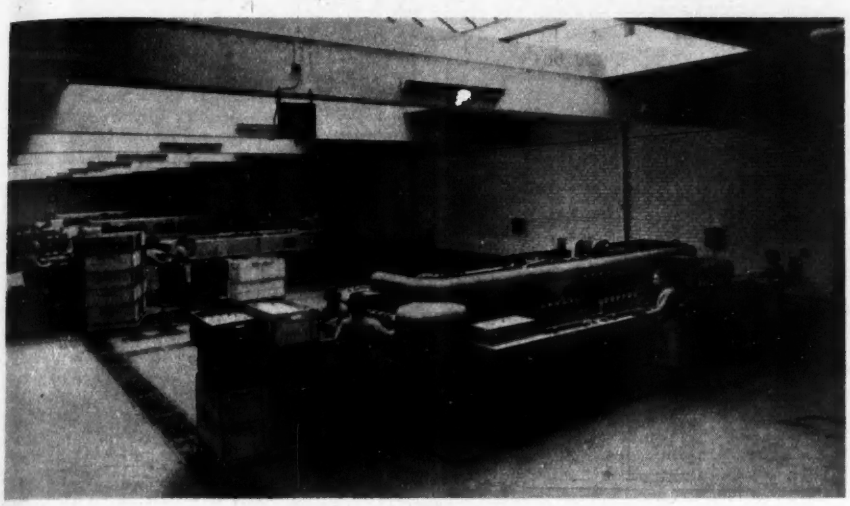
Steam supply for process work and heating is provided by two Economic oil-fired boilers, each rated at 8500 lb per hour at 100 lb per square inch. Steam is generated at 80 lb per square

Blending vats

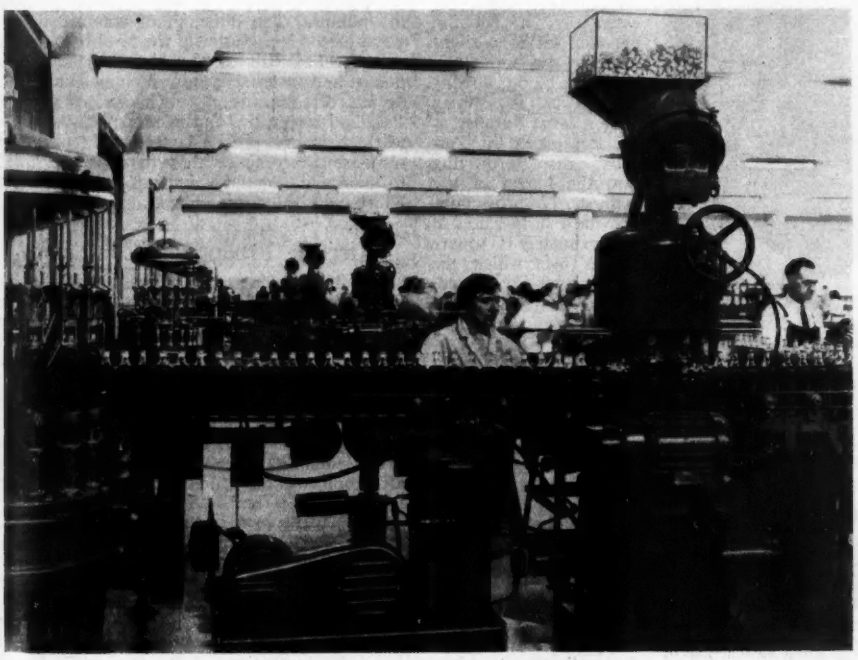
inch and reduced to 40 lb per square inch for heating. The feed water tank has a capacity of 2000 gallons and the oil fuel is stored in two 50-ton tanks. The South West Scotland Electricity Board supplies electricity at 11,000V to a substation, where it is converted to 415V by a 400kVA transformer. Casks containing matured single whiskies after delivery are hoisted to the fourth floor of the bulk spirit blending warehouse, where, after checking by H.M. Customs and Excise, they are laid out in the correct proportion ready for blending. This is carried out in three vats of 16,000 gallons capacity, seen in our photograph, and one of 5000 gallons capacity. To fill the vats about 170 casks at a time are " disgorged " into five stainless steel troughs consisting of two outer pairs, which are connected on the centre or header trough. The latter is connected to each of the vats by two 15in diameter pipes. Compressed air is released through perforated pipes at the bottom of the vats to perform a " rousing " operation and assist in the mixing. Afterwards the contents are run off into casks, which are removed to the bulk warehouse, where they lie for months to allow the " marrying " process to be completed.

After " marrying " the casks are transferred over the communication bridge by conveyor to the bottling premises, where the casks are " disgorged " into stainless steel troughs which lead to glass-lined storage vessels on the floor below. Here the whisky is prepared to the required strength. While this is being carried out bottles are removed from storage and pass through the washing and sterilising machines, which can be seen in our illustration, before before being moved by power conveyors through metal tunnels to the bottling hall. Here on an intermediate floor above the filling machines are twelve mild steel glass-lined vessels, four of 8909 gallons, six of 4825 gallons capacity and two of considerably smaller size. Each set of four vessels is coupled to two filling lines.

At present five automatic bottling lines are installed, three having a capacity of 300 dozen bottles per hour each and two of half that capacity. In each line is an automatic rotary filling machine, from which the bottles pass to a corking machine, both of which can be seen in the photograph reproduced below, and via conveyors to a sighting station for examination. Accepted bottles pass to a capsuling machine and then to a labelling machine—then, fully labelled, the bottles are conveyed to the wrapping table and packed into cases.



Bottle washing, sterilising and drying machines



Automatic filling and corking machines

Radiant Heaters

A NEW factory has been opened at Slough by Hanovia (Lamps Division of Engelhard Industries, Ltd.) for the manufacture of " Radisil " radiant heaters. These heaters have a spirally wound nickel chrome wire element, which is enclosed in a tubular silica sleeve, and the terminal bushes between which the element is held in tension in its sleeve are totally enclosed in housings at the ends of a sheet steel housing. The trough-shaped housing carries a chromium-plated brass reflector behind the element, and is fitted with mounting brackets by which it can be fastened in almost any desired horizontal position on a wall or ceiling. A sliding metal grille is fitted along the front of the heater. The use of the protective silica sleeve over the element combined with the enclosing of the terminals and fitting of the metal grille gives the heater a high standard of safety in use.

The heaters are made in two lengths of 26in and 48in and for domestic purposes the shorter unit is made with ratings of 300W, 500W and 750W, and the longer heater with ratings of 1500W or 2000W. Industrial 26in long models of the heater are made with ratings of 500W and 750W, and 47in models are available with elements of 1500W or 2000W. These industrial heaters are particularly well suited for space heating purposes when they can conveniently be slung from a ceiling and arranged alternately with fluorescent tube lighting elements. The reflector housing of the heaters can be adjusted through an angle of about 120 deg. to radiate the heat in any required direction. In addition to space heating, the makers are developing the new heaters for industrial drying purposes, where they are stated to have a number of applications owing to the fact that the enclosed element is protected from and unaffected by damp or steamy atmospheres.

An Oxidation Catalyst

VARIOUS attempts have been made to control exhaust fumes by means of catalyst installations, and Oxy-Catalyst Sales, Ltd., Henley Park, Guildford, a subsidiary of Vokes, Ltd., announces the production of an active and stable oxidation catalyst, " Oxycat." This has been evolved by Mr. E. J. Houdry, the originator of the petroleum catalytic cracking process, and has already been used successfully in the United States. The problem of overcoming industrial air pollution is mainly concerned with the combination of oxygen with elements such as carbon, hydrogen and sulphur ; the new catalyst is stated to hasten the reaction of oxidation and also to deal effectively with hydrocarbon solvents, sulphur compounds, ammoniacal fumes, and be used for the reduction of the oxides of nitrogen.

The " Oxycat " consists of two end plates, a tie rod and a number of streamlined elements coated with a film of catalytic alumina and platinum alloy. This film, which is resistant to high temperatures and thermal shock, converts obnoxious gases and dangerous fumes into their oxides, with evolution of heat. The units are arranged in a bed, side by side and end to end and in two, three or four layers, while ceramic spacers are placed over and between the end plates to tie the units together. To start the reaction the gas stream entering the catalyst unit must be at a minimum temperature of 500 deg. Fah. However, once started, the reaction will increase the temperature until equilibrium is reached. To ensure that the correct starting conditions are attained it is usual to fit a preheat burner, equipped with automatic controls, which cut out the burner when the desired temperature is reached.

ACHESON MEDAL AWARD.—The American Electrochemical Society has awarded the 1956 Acheson Medal to Dr. R. M. Burns, a senior scientific adviser to Stanford Research Institute. This biennial award is made for an outstanding contribution to " the advancement of any of the objects, purposes or activities fostered or promoted by the Society." The Foundation which, under the control of the American Electrochemical Society, sponsors the award, was set up in 1928 by Dr. Edward Goodrich Acheson, the centenary of whose birth is being celebrated this year.

Artificial Heart and Lung Machine

A HEART and lung simulator, which is designed to perform the functions of a patient's heart and lung during cardiac surgery, is shown in the accompanying illustrations. The idea behind this machine is attributed to Dr. D. G. Melrose at the London Post-Graduate Medical School. There, in collaboration with New Electronic Products, Ltd., London, W.1, a prototype machine was designed and built about four years ago and, later, with the help of the Nuffield Foundation, a second prototype was built.

The second machine proved to be satisfactory for clinical use and a production model was developed with a view to helping other cardiac centres to engage in this kind of research. This production version is designed and made by Electronic Products, Ltd., and Tricorn Designs, Ltd., of Rochester Row, London, S.W.1, helped with the production design.

As illustrated in Fig. 1, the complete machine is mounted on a trolley measuring about 3ft by 2ft by 2ft. The principle of operation is outlined diagrammatically in Fig. 2. The main components of the machine are the "oxygenator," which takes over the duty of the lungs; the pumps, which do the work of the heart by maintaining artificial circulation; and an electronic control panel. There are three pumps: one for venous flow, a second for arterial flow and a third for emptying the heart and returning to the machine all the blood that may be spilt during an operation. Each pump consists of a rubber or plastics tube, which can be compressed between two plates to give a pumping action; one plate acts as a back-stop against which the other plate compresses the tubing. The pumping plate is driven by a camshaft which imparts an undulating movement to it. The back-stop can be moved towards or away from this moving plate to vary the amount of compression. This adjustment can be made by manual operation of a shaft or by energising servo motors. The stroke volume can thus be altered and the output can be varied between zero and 5 litres at seventy-two pumping strokes per minute. At each end of the tubing there are valves which completely occlude the tubing at appropriate times in the pumping cycle. The cams operating them are arranged to provide a filling period of 55 per cent and ejection of 33 per cent. This is close to the filling and ejection times of the human heart

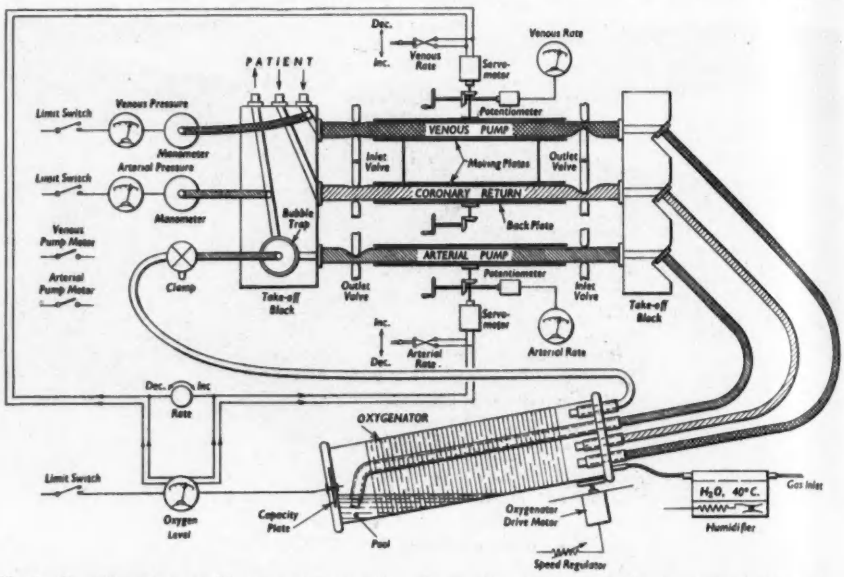


Fig. 2—Simplified diagram of heart and lung machine. Three rubber tubes squeezed between metal plates act as pumps to simulate heart action and an "oxygenator" takes over the function of the lungs

chambers. The pumps are driven by two ½ h.p. motors, and in the event of power failure the drive can be taken over manually by means of a crank handle.

During operation the veins and arteries leading to and away from the heart are clamped off to exclude the circulation from the heart, the body's demand being met by the machine. Tubes sealed into the main veins and arteries are connected to the venous and arterial pumps respectively. Blood passing through the venous pump is passed to the oxygenator, which is, essentially, a rotating cylinder set at a slight angle to the horizontal. There the blood, flowing by gravity, is spread over a large number of surfaces formed by "Perspex" discs projecting into the lumen of the cylinder. The projections provide a surface area of approximately 1·3 square metres over which the blood is re-oxygenated, with oxygen passed into the cylinder from a bottle via a humidifier. The oxygenated blood is withdrawn from the pool formed at the lower end of the oxygenator by the arterial pump and pumped back into the body.

The front panel of the control unit can be seen at one end of the trolley which contains the necessary switches for the electric motors and the electronic units for measuring continuously the pressures within the hydraulic circuit. If the pressures exceed a predetermined limit (which might involve the collapse of veins) the machine switches itself off automatically. The pressure measuring device consists of a magnetic core which is placed between the two coils forming the arms of a bridge and is attached to a pressure-sensitive diaphragm. The bridge is fed from an audio-frequency oscillator and any out-of-balance voltage is amplified to a level sufficient to operate a phase-sensitive demodulator which in turn drives a milliammeter calibrated in millimetres Hg. and a trip relay.

An additional control circuit ensures that the volume of blood in the machine is constant within narrow limits to simulate the delicate servo mechanism which, in a living animal, adjusts the uptake and delivery in the heart.

A true indication of the total volume of blood is given by the level of fluid at the lower part of the oxygenator. A brass disc fitted at this end is separated from the pool of blood by a "Perspex" disc of 1mm thickness. This combination forms an electrical condenser and changes in mean level produce appropriate changes in capacitance. This change, in turn, frequency-modulates an oscillator and any deviation from the preset frequency acts as a proportional controller to the two servo motors driving the back-stops of the pumps. The direction of rotation of the servo motor is such that if the level of blood in the oxygenator decreases, delivery of the venous pump and arterial pump are increased and decreased respectively. The servo loop is stabilised by positive and integral feed-back networks to ensure precise control with maximum response; in practice these circuits are stated to maintain the total volume of blood to about 2 litres within ±50 millilitres.

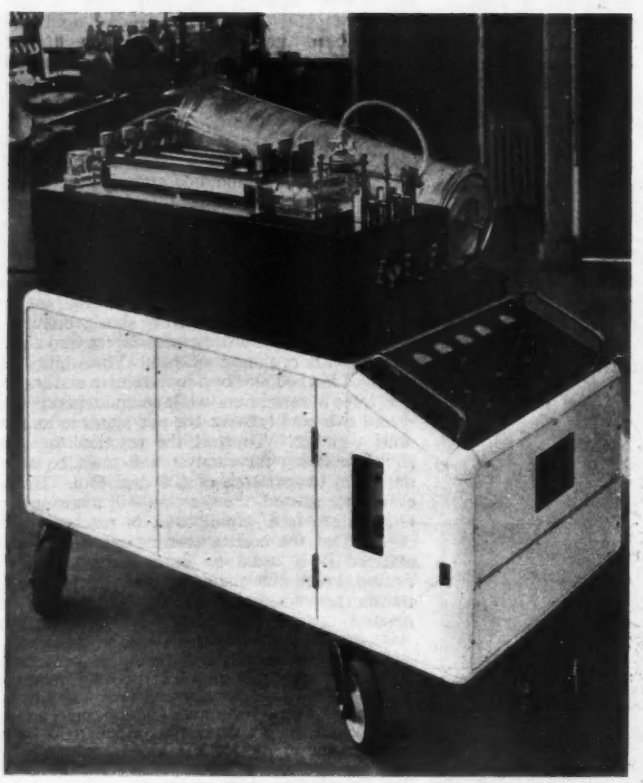


Fig. 1—Artificial heart and lung machine. It is designed to take over the functions of the heart and lungs after the heart-beat has been stopped by injection in preparation for cardiac surgery

Aircraft Production Conference

THE fifth conference on "Problems of Aircraft Production," held by the Southern Section of the Institution of Production Engineers, will take place at the University of Southampton on January 8 and 9, 1957. The theme will be "New Materials—New Methods."

The Minister of Supply, Mr. R. Maudling, will address the conference at luncheon on the Tuesday, after which K. Frydag will read the Lord Sempill Paper. The remaining papers that afternoon will be "Fatigue of Aircraft," by P. L. Teed; and "Electrically Controlled Machine Tools in Aircraft Production," by O. S. Puckle. Three papers will be discussed on Wednesday: "Hot Forming of Rolled Sheet," by R. G. Wilkinson; "New Applications of Welding Techniques in Aircraft Production," by N. K. Gardner, and "Chemical Milling," by A. W. Sheppard. Application forms are available from the Institution of Production Engineers, 10, Chesterfield Street, London, W.1.

U.S. Warships—Environmental Aspects of Improved Habitability

BY OUR NAVAL CORRESPONDENT

BOTH the Admiralty and the United States Navy Department have attached great importance since the war to improving the habitability of warships. Ships which fought in World War II, as originally designed, incorporated standards of habitability which at that time were considered reasonably adequate. But war complements and the addition of new weapons and equipment with the extra personnel required to operate them made constant encroachments on space allocated to personnel. The comfort and convenience of the ship's company had of necessity to give way to military requirements. The wheel has now, however, turned full circle. If men are to be attracted to the Navy and are to be willing to remain in it they must be made to feel that the Navy has kept pace with the improvement in the standard of living ashore, so far as design and military considerations permit. But the overriding reason for this new thinking is to increase the fighting efficiency of the ship. A ship's efficiency as a fighting unit is not dependent on any one factor, whether it be her guns, aircraft, equipment, hull or her crew, but on the product of all these factors. If the crew is only 50 per cent efficient the ship herself can be no more than 50 per cent efficient. And if a man is constantly subjected to excessive temperatures, bad ventilation and poor lighting and has no place where he can rest and sleep in comfort, his personal efficiency must inevitably deteriorate. It is now recognised, in fact, that, as with everything else in a warship, the purpose of a high standard of habitability is to make her the most effective fighting machine that modern technology, psychology and leadership can produce.

In designing a warship a compromise has to be reached between conflicting requirements and often, indeed, between one military characteristic and another. Where there is a conflict between a military and a non-military characteristic the former has always in the past been the overriding consideration. It was made clear, however, in a paper read by Mr. D. S. Berres—a senior official of the Bureau of Ships, Navy Department, Washington—to the United States Society of Naval Architects and Marine Engineers, that this is no longer to be the governing principle in United States warships of new design. The United States naval authorities have now defined habitability as a military characteristic and have directed that there must be no unapproved encroachment on "space normally available for the accommodation of the crew." No such directive is at present in force in the Royal Navy, but apart from the close collaboration which exists between the two navies, there is ample evidence, from the vast improvement in habitability standards in recently completed ships of the Royal Navy, that the Admiralty has it very much in mind. The chief value of the directive lies, of course, in its application to new ships. It ensures that the design of a new ship, with the armament, speed and equipment required by the naval staff, can only be accepted if it provides also for the highest possible standard of habitability. But it also discourages proposals involving further encroachments on crew space if the installation of new and modern equipment is contemplated when refitting and modernising existing ships. In his paper, Mr. Berres sets out the results of an exhaustive study, made by the Bureau of Ships, of the habitability standards which should be incorporated in future United States warships. As the Bureau's report has now been approved by the Navy Department, the following brief summary of the section dealing with the environmental aspects of habitability may be of interest.

Air Conditioning

The majority of existing ships have ventilated habitability spaces, i.e. weather air is used as the cooling medium. The design criteria for weather air is 88 deg. Fah. dry bulb and 80 deg. Fah. wet bulb, and obviously the living spaces level off at some hotter condition, even if a very large quantity of air is circulated. Ten years ago it was realised that the point of diminishing returns had been reached in the "increasing ventilation-quantity" approach and every new design warship, from destroyer upwards, since 1946 has been fitted with air conditioning in living spaces. From now onwards air conditioning is also to be fitted in ships smaller than a destroyer, but practical considerations of weight and space prevent its extensive application to existing ships. The air conditioning systems being installed are actually austere in nature. Replenishment air is furnished at a rate of only 5 cubic feet of weather air per minute per man. The design condition at full load is set at about 85 deg. Fah. dry bulb and 50 per cent relative humidity, which is the threshold of sweating for men at rest. However, since full load is rarely achieved, the plant capacity is used to maintain more comfortable conditions by setting thermostats to about 78 deg. Fah. Cooling coils are designed to limit humidity; humidity controls are generally not provided, nor are they necessary in these applications.

Lighting

As with air conditioning, World War II operating experience proved the inadequacy of the then existing lighting standards. A research and development programme was initiated in about 1946 that eventually led to the redesign of practically every lighting fixture the Navy uses. The foot-candle level of illumination has been raised in order of magnitude of 2 to 1. Uniformity of illumination has been achieved by establishing minimum acceptable ratios of maximum to minimum light intensity. New paints have been developed that: (*a*) minimise the brightness contrast between the seeing task and the immediate background, and (*b*) incorporate the desired reflectivities. The new lighting fixtures installed in living spaces are essentially of the fluorescent kind. They are shock-mounted and incorporate modern lighting design concepts stressing broader and more uniform distribution with minimum brightness ratios, minimum surface brightness, minimum glare and use of an upward component for illuminating the overhead. In addition, emphasis has been placed on detail or local lighting, such as the individual crew berth light. The new fixtures and standards have been incorporated into the specifications for new ships. They are being installed in existing ships whenever funds and availabilities permit but there are still a large number of relatively poorly-lighted ships in our Navy.

Noise

The recently issued specifications contain the first allowable limitations on acceptable noise levels for compartments. Previous specifications included acceptable levels for: (*a*) ventilation systems, and (*b*) for selected equipments. The current approach, accepted after considerable research, puts the problem on a more technical basis. That is, first, acceptable levels for compartments based on their use were established and, second, acceptable levels for the noise source were established. Essentially, three categories of spaces are considered.

Control Spaces.—Speech intelligibility is the over-riding consideration. It has been found that noise levels in octave bands below 300 c/s and above 4800 c/s do not have a serious effect on speech intelligibility. Consequently, maximum speech interference levels (S.I.L.) have been specified for these compartments. S.I.L. is defined as the arithmetic average of the decibel levels in octave bands between 300 c/s and 4800 c/s. S.I.L. varies with compartment size; it is being limited to between 50 and 60 decibels.

Living Spaces.—Comfort is the paramount consideration. With regard to comfort, it has been found that noise levels in each of the octave bands are of significance. Consequently, maximum levels have been specified in each band. Again the limits vary with compartment size. For compartments of from 2000 to 8000 cubic feet the allowable decibel levels vary from 82 at the low frequencies to 54 at the high frequencies.

Machinery Spaces.—Avoiding conditions that can cause deafness or extreme physical discomfort is the over-riding consideration. As with comfort, it has been found that each octave band must be considered, and maximum decibel levels have been specified. These levels vary from 115 at the low frequencies to 85 at the high frequencies. It has been long recognised that ventilation systems are the principal noise sources in living spaces. Previous specifications, even though they were based on overall noise levels for simplification, were found to be impractical and were often waived. These difficulties have been taken into account and, while the specifications may seem to be more complex, they are believed to be reasonable. In any event, if noise reduction is to be obtained, it will only be the result of more diligent effort.

Colour

Prior to 1951, two colours of linoleum tile, one bulkhead paint colour, one upholstery colour and four curtain colours were approved for use in living spaces. With some reluctance, because of the effect on the supply problem it was decided to increase this selection. To-day there are eight tile colours, nine bulkhead paints, five upholstery colours (all in a new material), and ships can use any colour they like in curtain or slip-cover materials. Furthermore, since the customer is the final judge of the effect of the colour scheme, ship personnel have been given almost unlimited choice in determining which colours they want and where. Restrictions for the most part are technical rather than æsthetic. For example, overhead paint colours must have a minimum reflectivity of 70 per cent; bulkheads not less than 50 per cent. These requirements limit any adverse effect paint might have on the lighting installation. Colourwise, they mean that the overheads will be white or at least quite light, and that bulkheads will be pastels. The approved paints also incorporate desired gloss values. In a sense, it is unfortunate that much of the recent publicity given to the habitability programme has emphasised the new colours. While few doubt the value of colour, it certainly should not overshadow the many other improvements that are being attained.

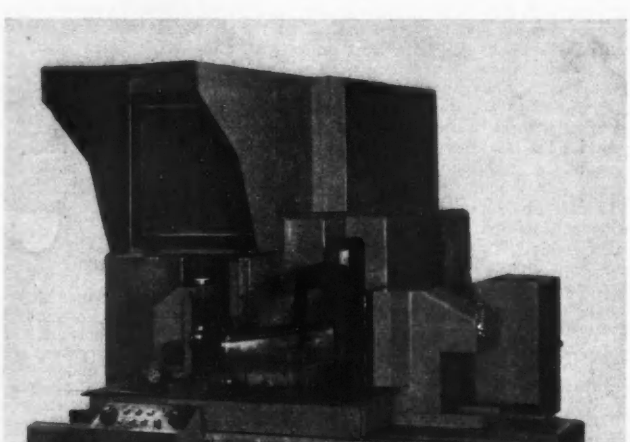
Modified Line of the London–Yorkshire Motorway.—In a statement in the House of Commons on March 28, 1956, the Minister of Transport and Civil Aviation announced his intention to proceed with the scheme for the first section of the London–Yorkshire motorway from south of Luton in Bedfordshire to Watford Gap, Northamptonshire, with a spur to Dunchurch for Birmingham traffic. Consideration has since been given to proposed alterations to the provisional line of route and three minor modifications which have the effect of slightly altering the line of the route near Tingrith, Bedfordshire, and Whilton and Kilsby, Northamptonshire, have now been decided upon. Modification at Tingrith meets the representations from the inhabitants of the village, who felt that their properties and the amenities of the neighbourhood generally would be injuriously affected. The deviation at Whilton has been made to avoid the demolition of habitable property and that near Kilsby on grounds of amenity and also to mitigate the disturbance to agriculture. The Ministry states that a draft Order under Section 3 of the Special Roads Act, 1949, making proposals for alterations to side roads and private means of access, which will be affected by the construction of the motorway, will be published, as prescribed by statute, within the next two or three months. There will then be a period of three months during which any person affected by the proposals in the Order may make objection to it.

Large-Capacity Projector for Inspecting Turbine Blades

PARTICULARS have been received from Optical Measuring Tools, Ltd., Maidenhead, of a large-capacity "Pantometer" which has been developed for the inspection of turbine blades up to 24in long, 6in chordal width and having a permissible thickness of 2in. It also incorporates means of checking the contour and size of any predetermined section as well as section displacement and width. In the instrument contour and size are checked by a stylus follower with optical reproduction of its path on a screen.

As shown in the photograph we reproduce, the turbine blade is mounted horizontally on the instrument table by means of a work head, or headstock, which has co-ordinate movements in the vertical and horizontal planes and rotational movement about the horizontal axis, each of these co-ordinate movements being actuated by micrometers. Two diametrically opposed styli are mounted on slides, by which each is connected to an objective lens. Mounted beside the screen, in such a manner that it rotates through the vertical plane, is a disc containing separate graticules of each blade section to be checked. The graticules are so arranged that light from the lighting unit passes through the graticule and objective lens and is transmitted to the screen where any observed image is 30× magnified. The screen contains a tolerance graticule in the form of concentric circles, the mean circle representing the diameter of the stylus at 30× magnification and the others representing permissible tolerances. As the stylus traverses the blade contour, its objective lens follows an identical path and projects the relevant part of the graticule to the screen; thus the image of the graticule is observed to pass across the screen and, if the blade is correct, through the tolerance zone.

In addition to the stylus carriages there are two positional indicators mounted on ball slides, and any displacement of section or twist is indicated by two "spot" graticules associated with the indicators. A setting plug is used to establish the correct position of the indicators, after which they are brought into contact with the leading and trailing edges of the blade, and any deviation is shown by the displacement of the "spots" on a small screen immediately below the main screen. Should there be no error, both "spots" coincide with the centre of the cross lines, but if an error is present this can be compensated for and measured by means of the micrometers on the work holding head.

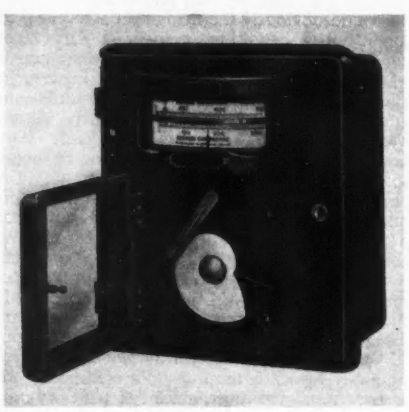


"Pantometer" projector for checking turbine blades up to 24in long and 6in chordal width. Provision is also made for checking contour and size of any pre-determined section displacement and twist

The principal operational movements of the instrument are power controlled and the table traverse, graticule location, stylus travel and positional indicators are all operated by push buttons.

Programme Temperature Controller

WE illustrate a direct-reading instrument made by Ether Ltd., Tyburn Road, Erdington, Birmingham, to give accurate indication and control of temperature in accordance with a predetermined time programme. It is intended mainly for controlling the heating and cooling cycle of a furnace charge and is designed to heat the charge at a predetermined rate, hold it at the soaking temperature for a given time, and then cool it as required.



In this programme temperature controller the measuring instrument is a galvanometer with an indicating pointer which operates a photoelectric system to control the heat source. A cam determines the time-temperature programme and sets the control pointer

The instrument is known as the "Transitrol 994." It consists of two units: an indicating temperature control unit and a time-temperature programme unit, housed together in a welded steel case, sealed against dust and moisture.

The indicating temperature control unit consists of a conventional galvanometer with an indicating pointer which operates a simple photoelectric system to control the heating medium.

The galvanometer is fitted with an "Alcomax II" magnet, a high-resistance coil, precision-ground hardened pivots and spring-loaded polished sapphire jewels. Calibrations are available for use with thermocouples or other temperature-sensing media. It is fully compensated for cold-junction variation and internal-resistance changes due to the temperature resistance coefficient of the copper moving coil. For final calibration, according to the specific length of the compensating lead used on installation, an adjustable rheostat is provided.

The instrument is equipped with a red index control pointer in addition to the temperature indicating pointer. The control pointer is fitted with photo-sensitive transistor, optical lens and low-level light source. When the transistor receives full illumination a relay is energised, giving external switching control. The temperature indicating pointer is fitted with a flag, capable of passing freely between light source and transistor, and when the desired temperature is attained the light source is cut off from the transistor, thus de-energising the control relay and shutting off the heating medium. The design of the optical system ensures that only a very small movement of the pointer is required to "make" and "break" the control relay, giving a very fine degree of control. Signal lights are incorporated to indicate "mains on/off" and "control on/off."

The time-temperature programme unit incorporates a single-phase, 230V, 50 c/s electric motor, mounted in a gearbox below the indicating temperature control unit to drive the cam on the front of the instrument at a selected speed. In contact with the periphery of this cam is the control arm, which is connected by a pair of precision cut bevel gears to the red index control pointer of the indicating temperature control unit. The face of the cam is graduated in time and temperature; time being marked from the periphery to the centre and temperature being marked by circles. This system enables a cam to be cut to suit any particular time-temperature programme. A gear train shown on the back of the gearbox permits varying time cycles to be selected. For any given motor a variation of eight speeds can be achieved by changing only one gear of the gear train.

An eccentric screw is fitted to the control arm to give vernier adjustment in correcting the errors in cam cutting. A limit switch lever positioned behind the cam can be set to switch off motor or heater at any given time of the programme. An involute cam is provided to give fixed control point on any position of the scale by switching off the motor and positioning the involute cam at any desired point of the scale required as a fixed control point. The instrument has a calibrated scale length of 6·5in and the average sensitivity is given as 65 microamperes for full-scale deflection.

Technical Reports

Experimental Stress Analysis in the U.S.A. and Canada. By A. F. C. Brown, B.Sc., A.M.I.Mech.E. H.M. Stationery Office. Price 2s. This is No. 1 in the series of Overseas Technical Reports, and was prepared by a member of the N.P.L. staff, who was attached to the scientific mission in Washington in 1954 and 1955. It deals with North American practice in electrical resistance strain gauging, photoelasticity, brittle coating, analogue and miscellaneous methods, and mentions the problem of aircraft heating in supersonic flight. The bibliography is classified under corresponding headings. Particular reference is made to the Baldwin-Lima-Hamilton Corporation who have refined the Saunders-Roe foil gauge by a photographic process of production, and sponsored a striking survey of the possibilities of strain gauging at temperatures up to 1600 deg. Fah.

The Analysis of Right Bridge Decks Subjected to Abnormal Loading. By P. B. Morice and G. Little. Cement and Concrete Association, 52, Grosvenor Gardens, London, S.W.1. Gratis.—An analysis based on distribution coefficients of the effects on bridges of heavy indivisible loads is described with the aid of worked examples. Design curves for the method are given. It is stated that preliminary results seem to indicate that, although the method is not readily applicable to skew bridges (hence, presumably, the word "right" in the title!), it may be safely used up to an angle of skew of 20 deg. Maximum structural efficiency in the distribution of abnormal loads is not always achieved if attention is given primarily to longitudinal moments. The authors consider that although the provision of transverse stiffeners will at first sight appear as just an additional cost, when abnormal loading is considered, the use of smaller main beams should cover any additional expense.

Towards European Integration: First Results for Coal and Steel. Compiled and edited by the Statistics Division of the High Authority of the European Coal and Steel Community. Luxembourg: The High Authority of the Eruopean Coal and Steel Community, Service de Publications, 27, rue Aldringer. Gratis.—The present booklet, the first of a series, outlines the achievements of the six member countries of the Community in their advance towards integration during the nearly four years the Iron and Steel Community has been in existence. Other booklets in this series will give a general picture of the emergence and importance of the Community, and will deal with the institutions of the Community and the Common Market, as well as with problems such as living and working conditions, financial operation, technical research and transport.

Industrial and Labour Notes

Trade Unions

Part 4 of the *Report of the Chief Registrar of Friendly Societies*, which has been published this week (H.M. Stationery Office, price 3s.), deals with the operations of trade unions during 1955. The report says that the membership of registered unions of employees increased from 8,357,000 at the end of 1954, to 8,517,000 at the end of last year. The total amount subscribed last year to union funds was £19,347,000, an increase of £966,000, and the total expenditure by the unions was £19,390,000, an increase of £1,637,000. The largest single item of expenditure, the report notes, was "working expenses," that is expenditure on maintaining trade union organisation for carrying out the primary object of regulating conditions of employment and managing provident benefits.

One section of the report deals with changes in the size and number of unions over the past thirty years. At the end of last year, there were 405 unions, compared with 482 in 1925. In 1925, there were 260 unions each with a membership of less than 1000, and by the end of last year the number of these smaller unions had dropped to 172. On the other hand, thirty years ago there were nine unions each with a membership of 100,000 and more; the number of unions in this category has now risen to eighteen. The most significant increases in membership have occurred in the following unions, the figures shown being the totals at the end of 1955. The figures in parentheses are those for 1925: Amalgamated Engineering Union, 953,000 (234,000); Transport and General Workers Union, 1,329,000 (376,000); National Union of General and Municipal Workers, 805,000 (314,000); Electrical Trades Union, 224,000 (29,000).

The amount paid out by the unions last year in "dispute benefits" was £649,000, the highest figure recorded since 1926, the year of the general strike. Compared with the preceding year, the group of unions classified as "metal, engineering and shipbuilding" showed a decrease of £108,000 under this heading, while the "transport and communication" group showed an increase of £322,000. This latter development, of course, was a consequence of the railway strike in June, 1955.

Wages and Labour Relations

In his chairman's address at the annual meeting of Eastwoods, Ltd., which was held on November 15th, Mr. G. W. A. Miller commented on some of the problems arising from wage claims and labour relations in industry. He said that the root cause of most of our present difficulties, and the main reason for anxiety about the future was the continuing rise in wages, since it must now be apparent to everyone that wage advances without increased production inevitably meant further price increases. As had been exemplified by the recession in the motor industry, it was now all too easy to be priced out of any market, and that inevitably led straight on to reduced production and unemployment with all its baneful consequences. It was sincerely to be hoped, Mr. Miller continued, that more realistic considerations would weigh with the trade union leaders when off the public platform, and that the true interests of the workpeople would be given paramount consideration, which, according to his interpretation, was a good wage for a steady job with continuing full employment.

Mr. Miller then went on to say that, having regard to the economic situation of the country, and particularly to the extreme pressure being brought to bear upon the export trades to lower their costs, it was not very satisfactory to find so many new wage claims coming forward which could only add seriously to manufacturing expenses, both at home and in the export markets. Foremost in mind were the demands from the building industry, covering about 1,000,000 men, together with those for the engineering and shipbuilding industries. Those demands, Mr. Miller observed, if settled only partially, would add hundreds of millions to our costs at a time when we were hard put to maintain the present situation, both as regards the cost of living and ability to compete in the export market. A "policy of equality," Mr. Miller added, required rather more than "additional smash and grab raids" into the reserves and investments of the nation. What it demanded was equality of work and effort, equality of sacrifice, and equality of responsibility.

Furthermore, Mr. Miller remarked, the T.U.C. attitude towards a forty-hour week was most unfortunate and unpropitious. It represented merely another disguised application for increased wages. No more labour whatever could become available than at present, and many of our industries were dependent upon foreigners to keep works in continuous production.

Plant Investment

In a statement accompanying the annual accounts of Tube Investments, Ltd., the chairman, Sir Ivan Stedeford, comments on the welcome increase in expenditure by industrial companies on new factories and modern equipment in the last two or three years. For the first time since the war—indeed, for a generation—British industry began during that period to spend more reasonable sums on renewing its productive facilities. But, the statement continues, the restrictive measures the Government has been compelled to take in the last eighteen months have now effectively damped down this new spirit, and at a time when much leeway remains to be made up. Sir Ivan says he does not question the policy adopted to check inflation, but about one thing he believes there is no doubt: whether or not we associate ourselves with the movement towards lower tariffs in Europe, British industry needs long years of heavy capital investment if it is to surmount the competitive struggle which has now begun.

The statement goes on to say that if the present hesitations lead to no more than a pause for consolidation after a period of growing investment, no particular harm has been done. But, Sir Ivan urges the Government "to end the present discouragement at the earliest possible moment." It takes a long time, he observes, to plan and to construct the modern productive plants with the competitive power to match those which will be challenging us in all our markets. In his statement, Sir Ivan suggests that the time has come for the nation to give industrial capital investment the "sort of moral priority which housing has had for the past decade." Let industry be given a run for a few years, the statement says, to spend capital on a massive scale. By those means, and by those means only, are we likely to succeed in expanding our exports and in bringing about a rising standard of living.

Iron and Steel

During October, British steel production averaged 419,100 tons a week, which represented an annual output rate of 21,791,000 tons. The Iron and Steel Board says that this is the highest rate ever recorded in October, though it was below the output achieved during the month of March.

Taking the first ten months of this year, steel output averaged 394,800 tons a week, and was thus running at an annual production rate of 20,528,000 tons, compared with a rate of 19,644,000 tons in the corresponding period of last year. Pig iron production during the first ten months of this year averaged 251,600 tons, which represents an annual output rate of 13,083,000 tons. The Iron and Steel Board has stated that steel output may be affected by the interruption of oil supplies from the Middle East. The industry's consumption of fuel oil is over 1,500,000 tons a year, but the Board says it may be possible by the substitution of alternative fuels to offset to some extent the reduction in supplies which has been announced.

In its latest monthly statement, the Board gives some particulars as to the steel industry's stocks of raw materials and also about stocks of finished steel. At the end of October, stocks of imported iron ore at works and ports amounted to 2,487,600 tons, stocks of iron and steel scrap were 915,000 tons, and pig iron stocks amounted to 632,200 tons. At the end of September, producers' stocks of finished steel were 1,452,400 tons, while stocks held by merchants and consumers amounted to 3,999,000 tons.

Coal Output and Stocks

The Minister of Fuel and Power was asked in Parliament on Monday what arrangements he was making to increase imports of coal this winter, in view of the reduction in oil imports. In his reply, the Minister said that coal stocks were good, and it was too early to assess what effect the reduction of oil imports would have on coal import requirements. The position would, however, be kept under review.

The latest returns by the Ministry of Fuel and Power show that on November 10th distributed coal stocks amounted to 19,880,000 tons, compared with 19,490,000 tons on the corresponding date last year. When the undistributed stocks at collieries are taken into account, the total is rather more than 23,000,000 tons. Last week, there was a slight increase in coal output, the quantity gained being 4,730,000 tons. Total coal output in the first forty-five weeks of this year was 191,114,200 tons, which was about 1,500,000 tons more than in the comparable period of last year. The increase has been brought about by the larger output of coal from opencast sites, the deep-mined production so far this year having been at much the same level as last year. Coal imports, however, so far this year, at approximately 4,800,000 tons, have been about 50 per cent of the quantity imported in the first ten months or so of 1955.

At the beginning of this week, it was stated that the consultative committees operating in the various divisions of the National Coal Board were to seek means of arresting the falling trend in deep-mined production. These committees have been asked by the National Consultative Council for the industry (on which the trade union as well as the Coal Board are represented) to make suggestions for ensuring that this year's total output from the deep mines will not fall below that of last year.

Basic Materials' Prices

The Board of Trade says that, following the upward movement of basic material prices in August and September, the index fell in October by 1·1 per cent to a level only 0·8 per cent above July when the Suez crisis started. The price index (June 30, 1949=100) for basic materials used in manufacturing industry (with the exception of food manufacturing) stood at 155·4 at the end of October. The price index number for fuel used in manufacturing industry was 166·8. It is explained that the decline in October was due mainly to lower prices for copper, wool, rubber, hides and skins, and lead. Among the few commodities which rose perceptibly in price, however, were tin ingots (increase of 2·2 per cent), raw jute (increase of 5·1 per cent), and some imported heavy steel scrap. The Board of Trade says, however, that, as the index is compiled from the average monthly prices for October, it does not reflect the significant increase in the prices of copper, rubber, tin and jute which followed developments in the Middle East at the end of the month.

The index numbers for materials used in the mechanical engineering and electrical machinery industries fell by 0·5 per cent and 1·2 per cent to 177·8 and 185·8 respectively (June 30, 1949 =100). The decrease in both these indices was due primarily to lower prices for various brass and copper items, including brass strip (down 4·9 per cent) and copper sheets (down 5·7 per cent). The heavier weight of non-ferrous items in the electrical machinery materials index accounts for the fact that it declined more than the index for mechanical engineering materials. During October, there was little movement in the index for building and civil engineering materials which stood at 143·1.

Liquefied Petroleum Gas in Bulk for Industries in South Africa

BY OUR SOUTH AFRICAN CORRESPONDENT

IN past years industries in South Africa requiring gaseous fuel have relied on producer gas plants, except in some instances where town gas was available. Certain branches of South African industry, however, have been aware of the value of liquefied petroleum gas for some years and have, in the past, imported filled cylinders from the U.S.A. for use in their specialised processes. This gas can be used whenever heat is required for high combustion efficiency conditions, and particularly for localised and close control conditions. Its approximate composition is given by :

	Per cent
Propane	30
n-butane	35
Iso-butane	35

The delivery in September last of the first rail tank wagon (Fig. 1) of this liquefied gas from Durban by the Standard Oil Company of South Africa (Pty.), Ltd., to the Consolidated Glass Works at Wadeville, Germiston, marks a new era in industrial development in South Africa. Fig. 2 shows the 10,000-gallon capacity gas tank installed at these works. This successful railway bulk delivery means that gaseous fuel of high calorific value (approximately 3000 B.Th.U. per cubic foot) is now available in bulk supply to industries in South Africa, regardless of their location on the rail routes.

Indicative of its value in specialised industry is the fact that hitherto it had not been possible to undertake, for example, certain processes of glass manufacture with previously used heating means, but with the advent of this gas, such processes, among others, as fire finishing and polishing of glassware, can now be undertaken to impart the extra finish required for the highest quality glass products. For processes requiring lower temperatures, gas proportioning devices are installed.

The recent provision of special rail tank wagon facilities has now made it possible for South African industries to have the benefit of clean gaseous fuel delivered to their works in liquid state under pressure. Within short distances of the Durban refinery of the Standard-Vacuum Refining Company, which produces the gas marketed in South Africa by the Standard Oil Company, the gas is delivered in bulk by road tank wagons. Additional supplies, in smaller quantities, are available in cylinders.

The rail tank wagons were built by the South African Railways to specifications and designs agreed with Standard Oil Company technical advisers. At present four tank wagons are in commission, and the number is to be doubled early in 1957. Each wagon can transport 6400 gallons of the liquefied gas. By comparison with a normal railway petrol tank wagon, the barrel of which weighs 3 tons when empty and is constructed of ¼in to ⅜in plate, a liquefied petroleum tank wagon weighs 12 tons when empty and is constructed of 1½in plate to withstand the high vapour pressure.

The gas is liquefied under pressure for ease of transporting, handling and storing. As the pressure is reduced to a predetermined value for use, it becomes a gaseous fuel of constant heat value, thus permitting easy and strict temperature control in all applications. It is perfectly safe to handle and makes for exceptionally clean usage. Compared with solid or liquid fuels, such as coal and furnace oils, it eliminates to a large extent such problems as handling and disposal of ash on premises. It is relatively free from gum, sulphur and other impurities inherent in solid and liquid fuels. The gaseous products of combustion being virtually inert, make it an ideal fuel for many industrial application.

Industrial Handling and Uses

General practice in industry is to employ a two-stage reducing system to ensure constant pressure control. The pressure is first reduced at the bulk storage plant to, say, 8 lb to 10 lb per square inch, the gas at this pressure being distributed throughout the works, with a further reduction to the desired burning pressure at the actual point of application, usually about 1lin water gauge. Approximately 25 to 30 cubic feet of air is required for complete combustion of 1 cubic foot of gas. The products of combustion of 1 cubic foot of gas are :

Nitrogen	20 to 25 cu. ft approximately
Water vapour	4 to 5 cu. ft approximately
Carbon dioxide	3 to 4 cu. ft approximately

The fact, as already stated, that the gas is relatively free of gum, sulphur and other impurities, readily permits its use for direct firing in such applications as paint drying ovens, bread baking ovens, forge furnaces and metal treating furnaces.

General characteristics of the propane/butane mixture are as follows :—

Vapour pressure	225 lb per sq. in (max.) at 105 deg. Fah.
Residue test	2 mg. per 100 c.c. (max.)
Total sulphur	15 grains per 100 cub. ft (max.)
Odorant	1 ethyl mercaptan/10,000 U.S. gallons
B.Th.U. per cubic foot ...	3000 approximately
B.Th.U. per Imperial gallon	122,000 approximately
Specific gravity	0·55
Pounds per Imperial gallon	5·5
B.Th.U. per pound	21,200

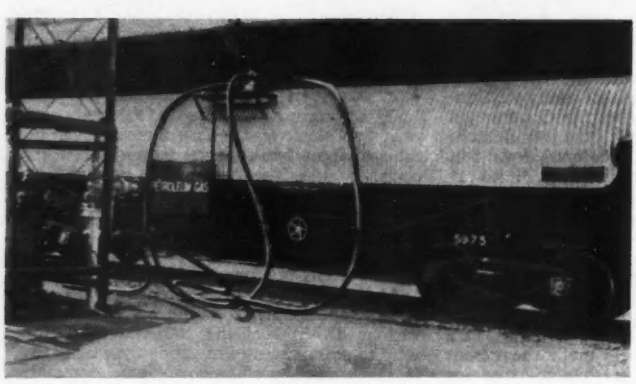


Fig. 1—Rail tank wagons are now being used in South Africa for transporting petroleum gas in bulk

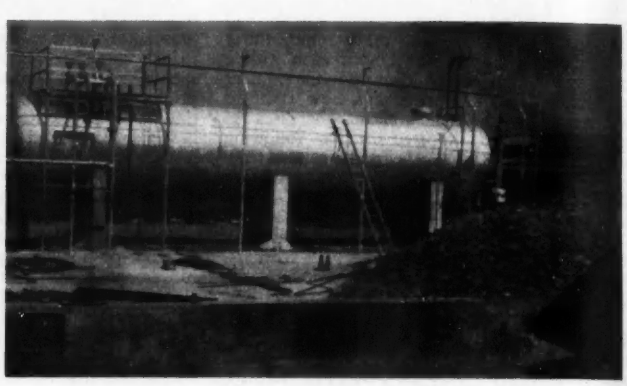


Fig. 2—10,000-gallon liquefied gas tank at glass works in South Africa

A number of South African industries have already switched to plant for the use of this fuel and others are following now that it is available in bulk delivery.

Amongst other industrial users of the gas are metal container manufacturers, motor assembly plants and cereal manufacturers.

Domestic Uses of L.P. Gas

Bottle-filling plants, as shown in Fig. 3, have been installed at various centres on the premises of appointed liquefied petroleum gas distributors to domestic users.

In the domestic field the gas is a good fuel for cooking appliances, water heaters, absorption refrigerators, space heaters and incandescent lighting. Its availability in cylinders throughout the country is particularly a boon to farmers and rural householders. With locally manufactured domestic appliances now available for such purposes as indicated above, substantial developments can be anticipated in South Africa in this field.

Fig. 3—Bottle-filling plants such as this are being constructed at various centres for distribution of gas to domestic users

Port Shepstone Bridge

A START has been made with the fifteen-span road-rail bridge over the mouth of the Umzimkulu River at Port Shepstone. By next month it is hoped that the construction of the first six spans from the Port Shepstone side will be completed, and it is planned to have the complete bridge ready for use at the end of 1958. The mouth of the river will be kept free for future use of small craft and to avoid the river silting up and damaging low-lying properties and industries on the river banks. The bridge will be 1200ft long with fifteen 81ft spans. It will carry the national road and the broad gauge railway line across the mouth of the Umzimkulu River.

Bonn Radio Telescope

After fourteen months' construction, the new radio telescope of Bonn University on Mount Stockert, near Münstereifel, was officially inaugurated. The following article contains some notes on the design and construction of the instrument. It possesses a reflector of 25m diameter, with a focal length of 7·45m, the surface being formed by aluminium alloy sheet, perforated in order to reduce wind forces, weight and, in particular, thermal radiation. The instrument is intended for the measurement of 21cm-radiation from interstellar hydrogen and for radar research.

THE construction of the radio telescope of Bonn University on Mount Stockert goes back to 1952, when the Gesellschaft zur Förderung der Radioastronomischen Forschung was founded. In October, 1954, the overall direction of the work was handed over to Telefunken G.m.b.H., and work on the site commenced in July of last year. The building of this installation required a sum of about DM.3,000,000, which was provided by the Federal and Lander Governments, in particular Nordrhein-Westfalen, and by industry. The official inauguration took place on September 17th last.

The Stockert radio telescope, which is shown in our first illustration, has a parabolic reflector, 25m in diameter, which is mounted on a reinforced concrete tower and can be pointed in any direction of space. Its design has its roots in the Telefunken radar sets built before and during the last war, in particular the "Würzburg Riese" (1941), which had a 7·5m diameter reflector and a range of 70km, and of which 1500 sets were built. More recently, in 1951, this equipment was successfully used in Holland to receive cosmic radio waves in the 21cm band.

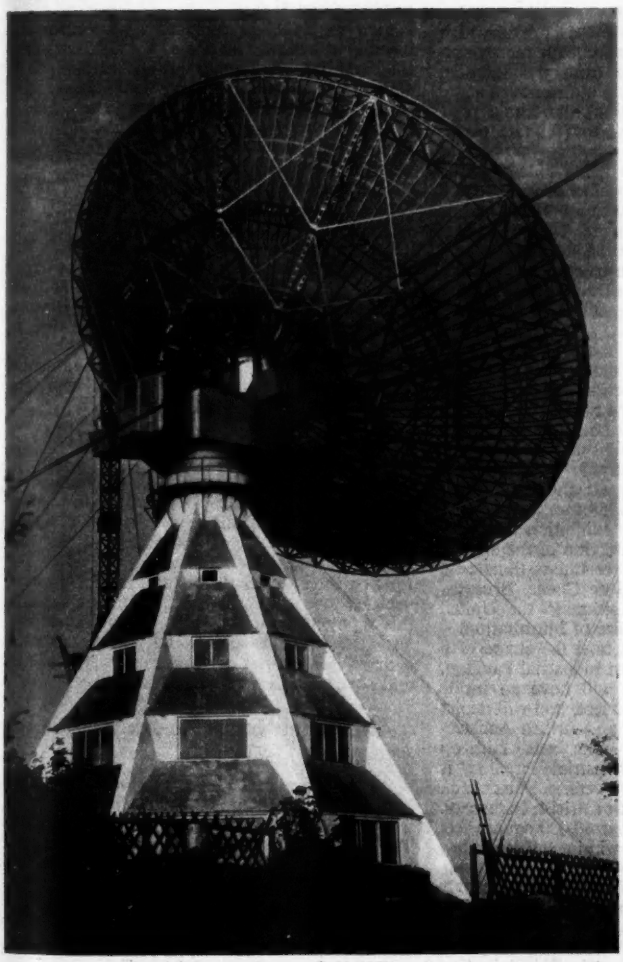
From a mechanical engineering point of view, the most interesting item is the reflector. It presents an area of some 500 square metres of light alloy sheet of 2mm thickness. About 70 per cent of the metal was removed by punching out holes 10mm square, leaving 2mm of metal between the squares. This has the effect of reducing wind forces by about 20 per cent. In addition to the considerable weight reduction, the focusing of heat rays is reduced. It is still further decreased by anodising the metal, thus increasing the scatter of the heat rays. Electrically, the mesh is nearly equivalent to solid metal.

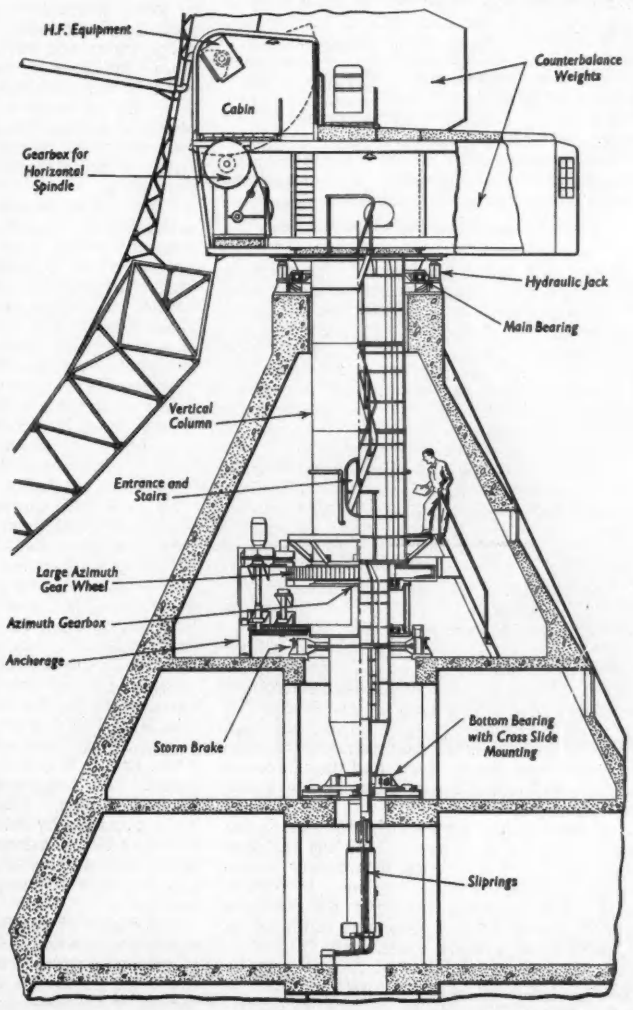
In a mirror of this size, one of the chief problems is to maintain its shape accurately under all normal conditions. In the Stockert instrument deviations from the parabola do not exceed ±5mm for winds up to 15m per second. The sheet metal mesh is supported by a framework consisting of a twelve-sided lattice steel ring 12·5m in diameter, which carries a light alloy framework comprising twelve radial girders, thirty-six main and forty-eight ancillary spars. Of the total weight of 20 tons, the steel ring accounts for about one half. It has been designed to withstand wind loads of up to 54 tons (corresponding to a hurricane of 42m per second) and a snow load of 10 tons.

The mirror is hinged to a platform which is rotatably mounted on top of the tower, the fork member carrying two 3-ton counterweights and the platform one of 20 tons. The tower is in the form of an octagonal cone 17m high. Together with its superstructure, it weighs 1100 tons, giving a pressure on the bedrock foundations of approximately 3 kg per square centimetre. Overall height, with the mirror in the vertical position, is 35m. The tower comprises four floors and a basement. In the basement are installed the transformer sub-station and emergency generating plant. The ground floor houses the receiver (the spectrometer) and various items of control equipment. First and second storeys contain scientific laboratories, while the third and fourth storeys contain the vertical column and its drive. The building is electrically heated. Total installed capacity is 260kW, of which 165kW is for heating. All electrical installations including lighting are carefully earthed and screened.

The mirror can be rotated through a full circle and elevated by just over 90 deg. The reason for choosing an azimuth mounting was that with a parallax mounting a certain amount of deflection would have been difficult to avoid; moreover, the azimuth mounting is more suitable for radar research for which the telescope is also to be employed.

As may be seen from our second illustration, the 69-ton rotatable vertical column extends through the two uppermost storeys of the tower. The column is hollow and permits access to a cabin at the top which houses the driving gears for the horizontal axis and part of the high-frequency equipment, which tilts with the





(Left) Radio telescope on Mount Stockert, with a 25m diameter parabolic reflector. The reinforced concrete tower houses the main portion of the electronic equipment, the drive of the vertical support column, servo-controls and mains supply. (Right)—Part section through top of radio telescope tower

reflector, thus obviating the tuning difficulties which arise with a flexible connection. The total movable weight, which with maximum snow load may amount to 125 tons, is taken by a very large ball bearing near the top of the column. This bearing, made by SKF Kugellagerfabriken, Schweinfurt, has internal and external diameters of 2·2m and 2·66m, respectively. The races are of unhardened silicon manganese steel of 120 kg per square millimetre ultimate strength. The bearing contains forty-four steel balls of 127mm diameter. Cleaning and replacement of balls can be carried out by hydraulically jacking up the top portion. Arrangements have been made for subsequent adjustment of both the vertical and the horizontal spindles. These may become necessary because of ground movements.

Approximately half-way up the column the main drive wheel is situated, together with the driving mechanism, which, in view of the possibility of later adjustment which has been mentioned, is supported on the column itself and anchored to the building. Extreme care was taken with the manufacture of the driving wheel on which the accuracy of the drive largely depends. With a diameter of 3m, it has a maximum pitch error of 8μ between adjacent teeth and an accumulated error of 30μ between any two teeth. During works assembly the mounted wheel showed a pitch circle diameter radial error of 0·02mm. For radar and for astronomical purposes, two widely different speed ranges are required (see Table I), and a mechanical gear change is provided to achieve the change-over. A servo-system incorporating a mechanical analogue computer is used for converting declination and hour angle into azimuth and elevation.

TABLE I—*Drive Speeds for Stockert Radio Telescope*

	Radar		Radio-astronomy	
	Maximum speed (deg. per sec.)	Gear ratio	Maximum speed* (min. per sec.)	Gear ratio
Horizontal axis	1	1 : 7200	0·05	1 : 100800
Vertical axis	1	1 : 7200	0·5	1 : 1008000

* Minimum speed = 5 per cent of maximum value.

Great care had to be taken with the assembly at the site. The components of the mirror were brought up by rail and finally by road, and were assembled on a specially designed concrete foundation and supporting frame, as had been done previously during the works assembly. The reflector mesh had to be riveted in position during periods when there was no sunshine, in order to avoid distortion. The positioning of the reflector constituted the most difficult part of the work, and was planned by means of a 20 : 1 wooden model. Two cranes lifted the reflector, face upwards, by means of the supporting frame, after which the counterbalance weights were attached to the fork. It was then raised into position.

The first task of the Bonn radio telescope will be an investigation of the 21 cm emission from interstellar hydrogen within the Milky Way. Owing to our own position within the galaxy, its structure has not yet been definitely established. If it is a spiral system then interstellar hydrogen may be expected to be concentrated in the arms of the spiral, as is the case with other such systems. Radio-astronomy can help to locate these clouds of gas, and their direction and speed of motion can be determined by means of the Doppler effect.

Of the principal firms which took part in the work, Telefunken G.m.b.H. held the technical supervision and developed the receiver equipment. The 25m reflector was made by Metallwerk Friedrichshafen (formerly the Zeppelin works), the mechanical parts were produced by ALKETT (Altmärkische Kettenwerke G.m.b.H.), and the steering and servo-technical part by A.E.G. The building of the tower and installation of services was done by the building department of Bonn University.

Brussels Universal Exhibition, 1958

Site work in preparation for the Universal and International Exhibition to be held in Brussels from April 17 to October 19, 1958, is now well under way. The exhibition, on which over £80,000,000 is being spent by the Belgian Government alone, will cover an area of 500 acres, equal to three and a half times the area of Hyde Park. Its general theme, to which all exhibitors must adhere, is " The contribution of the different countries of the world to the advancement of mankind and a better understanding between peoples." Fifty-three countries will be exhibiting in national pavilions, and in addition there will be special exhibits by international organisations, including the Council of Europe, the United Nations Organisation and its specialised Agencies, the Organisation for European Economic Co-operation, the European Coal and Steel Community, and the International Red Cross. The participating countries will emphasise their scientific, industrial and cultural achievements, rather than individual products.

The exhibition site on the Heysel Plateau measures approximately 2 miles by 1 mile. It adjoins the Royal Palace at Laeken, some 2 miles from the centre of Brussels. The exhibition grounds are used annually for the Brussels International Trade Fair. Buildings from the 1935 International Exhibition are being enlarged and will house the Belgian section in 1958. Adjacent to this part will be the Belgian Congo section and an ornamental garden illustrating the four seasons. To the east will be built the various other national pavilions, while right in the centre a building 300ft high and called the Atomium is under construction.

In view of the size of the area and the number of visitors expected—some 30,000,000 persons, it is thought, will attend—much attention is being paid to traffic arrangements. Within the exhibition grounds, people will be able to travel by narrow-gauge trains and cable railways. Among the more ambitious projects are a tunnel which will take the trains right underneath the exhibition, and an aerial bridge from the Leopold Memorial to Osseghem Park, a distance of some 900 yards. In Brussels itself, the whole road system is being reorganised to facilitate traffic circulation.

These developments are being aided by the setting up last year of an independent Road Authority which is to last until 1969, and is empowered to borrow up to 30,000 million francs. Its task is to undertake all road modernisation and motorway construction. The first public issue of 2500 million francs at an interest of 4½ per cent per annum is stated to have been immediately over-subscribed.

To ease traffic on the ring boulevards and radial streets of Brussels, urban motorways with two through lanes in each direction are being built. The system will include eight tunnels and a large viaduct, while at the Porte Louise there will be three decks of traffic : trains and local traffic at ground level, through traffic on two levels below. Most of these tunnels and the viaduct are planned to be ready by 1958.

The work of getting the exhibition ready on time is under the overall direction of the Société de l'Exposition Universelle et Internationale de Bruxelles en 1958, 10, Rue de Chene, Brussels. Representative of the exhibition in the United Kingdom is the Central Office of Information.

British participation will take the shape of a Government Pavilion and an Industrial Pavilion. The Government Pavilion will have an inside area of about 25,000 square feet, and will depict " The British Way of Life and British Achievements." Its foundation stone was laid on November 20th. The Industrial Pavilion is being organised by British Overseas Fairs, Ltd., on behalf of the Federation of British Industries. It will have an area of about 60,000 square feet and will also be started within the next few weeks.

The whole of the British area covers 21,000 square metres (about 5 acres), and in addition to the two pavilions there will be a cinema, a traditional English inn, and a number of shops for the sale of consumer goods. The British section will be only slightly smaller than that taken by the U.S.A., U.S.S.R., France and Holland, each of which is taking the maximum space of 25,000 square metres. Germany will have 18,500 square metres, and of the Commonwealth countries Canada will exhibit on a site of 11,000 square metres. Canada was the first country to start building, the foundation stone of its pavilion being laid on September 3rd.

At a recent Press conference called by the British Electrical and Allied Manufacturers' Association (Beama) the great importance of this prestige occasion to this country's industry was stressed. The decision of Beama to organise a collective exhibit is being followed by other trade associations and groups of companies. The exhibit of the electrical industry, participation in which is open to all firms and associations connected with this sector, will deal with the generation, transmission and utilisation of electricity, both at home and overseas, and will cover the whole field from heavy equipment to domestic appliances, as well as future plans for research and development.

VDI Annual Report for 1955

The Verein Deutscher Ingenieure has issued its annual report for the year 1955, from which it is seen that membership as well as activities have greatly increased. At the end of last year individual membership amounted to 31,461. New admissions totalled 2603, among them 446 university graduates, 887 technical college graduates, 264 persons with part-time or no academic training (probational members), and 1006 students. The number of sponsoring members increased by 197 to 850.

In place of an annual meeting there was held last year a special meeting with the theme " Der Mensch im Kraftfeld der Technik." Over 800 persons attended this two-day congress, which dealt with important aspects of the influence of modern technical civilisation upon the individual.*

New regulations, approved by the members' meeting at Münster on May 17, 1955, reorganise the VDI into five main groups (dealing with general questions affecting engineers), and twenty-one special sections (which deal with a wide variety of technological matters). The work of these sections during the year is described in detail in the report.

The publishing activities of the Verein Deutscher Ingenieure are carried out by the VDI-Verlag G.m.b.H., as the publishing concern has been renamed as from July 1, 1955. The Institution's journal was officially renamed *VDI-Zeitschrift* (abbreviation VDI-Z) as from January 1, 1955. A new monthly journal, *Luftfahrttechnik*, appeared for the first time in May of last year.

On September 1, 1955, Regierungsbaumeister a.D. E. Kothe retired as Director and was succeeded by Dr.-Ing. H. Grünewald.

Swiss Car Imports

New increases are reported in the number of motor vehicles imported into Switzerland during the third quarter of this year. The actual figure, 16,781 motor vehicles, exceeds that for the corresponding period of last year by 3610. For the first three quarters, the total is 54,370 motor vehicles of a total value 310·5 million francs ; this represents an increase of 13 per cent over last year which is mainly due to an increased demand for vehicles of medium size, while large and small vehicles showed little change.

Aluminium-Industrie-Aktiengesellschaft

It is announced by Aluminium-Industrie-Aktiengesellschaft that its head office has moved to Feldeggstrasse 4, Zürich (P.O. Box Zürich 34). The removal of the sales department to Buckhauserstrasse 5, Zürich (P.O. Box Zürich 48), took place last spring. The company's subsidiary, Allega, Ltd., has been at the latter address for many years. The research institute remains at Neuhausen/Rheinfall.

* The collected lectures have since been published by VDI-Verlag G.m.b.H., Düsseldorf.

Fabrication of Fuel Elements for Nuclear Reactors

BY OUR AMERICAN EDITOR

No. I

The growing interest in the commercial applications of atomic energy has led to more than twenty American firms entering the field of producing fuel elements and related reactor components. This development is encouraged by the U.S. Atomic Energy Commission, which now purchases its fuel element requirements from private industry. In line with the majority of current reactor designs, most of the fuel elements now being manufactured are of the flat plate form. This article primarily deals with flat elements and reviews the special fabrication methods required in their production.

IN the past few years the rapid growth that has occurred in the application of atomic power in the United States has led to much development work being conducted in the fabrication of fuel elements for nuclear reactors. It is now generally believed that the successful utilisation of the heat of the fission process for power generation and other industrial purposes largely depends on the proper design of the reactor core and its fuel element components.

In general, the basic fuel for a reactor consists of uranium 235 either in combination with uranium 238 as it occurs in Nature, or in an enriched form, such as that obtained from a gaseous diffusion plant. An increasing concentration of uranium 235 decreases the size of the critical mass necessary to produce a chain reaction. Uranium 238, as a fertile material, can be converted into a fuel by exposure to the neutron flux within a reactor. This reaction forms plutonium 239, which in turn can be separated and used as an atomic fuel. Similarly, thorium 232 can be converted to uranium 233 by the absorption of neutrons and subsequently can also be used as a reactor fuel.

Fundamental Design

Reactor designs have been classified by various standards. One of these standards of classification is based on the energy of the neutrons used to produce fission. Thus, the thermal reactor depends on low energy neutrons and uses a graphite or heavy water moderator to slow down the velocity of the produced neutrons. The intermediate reactor operates with neutrons of intermediate energies. Finally, the fast reactor uses neutrons of high energy in the neighbourhood of 1MeV.

All the above three reactor designs may be of either the heterogeneous or the homogeneous type. In a heterogeneous reactor the fuel is in distinct shapes, such as rods, slugs, or plates placed in a solid or liquid moderator. In a homogeneous reactor the fuel material is mixed with the moderator, such as in a solution, and is distributed uniformly throughout the reactor core. The core of a reactor is generally considered to be the most important part of the machine. It usually consists of a housing containing the fuel element arrangement, control rods and cooling facilities. Fig. 1 shows the Geneva Conference Experimental Swimming Pool reactor core with its cadmium control rods and uranium-aluminium fuel element plates separated by ordinary water acting as moderator and coolant. The design of a reactor core aims at facilitating the maximum possible rate of heat generation. Generally, the size and geometry of the reactor fuel elements are determined to suit the required heat transfer area within the core and the required volume of coolant and moderator. Thus, within the permissible limits of fabrication cost, the most desirable fuel element configuration will offer the greatest heat transfer surface per unit of core volume and per pound of fuel.

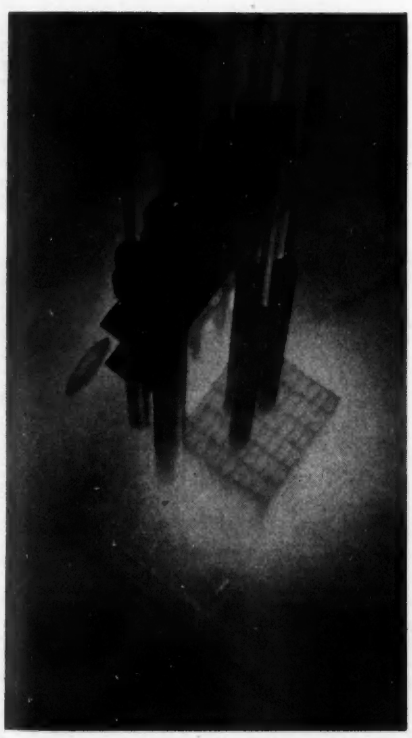


Fig. 1—Core of Geneva experimental swimming pool reactor with control rods and fuel element plates separated by water

Since the Geneva Conference in August, 1955, much information concerning nuclear fuel element design and fabrication has been declassified in America, and full-scale models of fuel element assemblies have been displayed by such concerns as the Babcock and Wilcox Company, the Metals and Controls Corporation, and Sylvania Electric Products, Incorporated, at various expositions during the past year. The recent activities of these companies are representative of the current trend among private industrial firms to enter the fuel element fabricating field and to offer a custom design and fabrication service. As a leading manufacturer of steam generating equipment for the utility industry, it is a logical step for the Babcock and Wilcox Company to enter this new field in order to be able to supply the nuclear fuel to its customers constructing atomic power stations. The broad experience obtained by the Metals and Controls Corporation in the fabrication of both solid and composite metals formed an excellent background for the company to enter fuel element manufacture, and the firm's Nuclear Products Division has been engaged in this field since 1952. The Atomic Energy Division of Sylvania Electric Products, Incorporated, is to-day one of the largest single groups in the United States exclusively engaged in the manufacture and development of fuel elements and components for atomic reactors. The company's broad experience in the metallurgy of high-purity, high-temperature materials has been a valuable basis upon which to build up its fuel element work, and since 1947 Sylvania has been active in nuclear projects for both the U.S. Atomic Energy Commission and private industry.

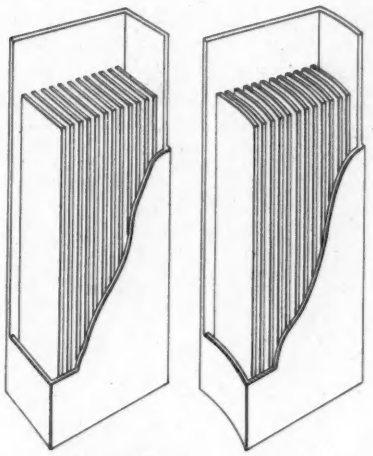


Fig. 3—Straight and curved plate designs of flat fuel elements

The original "know-how" in the design and fabrication of fuel elements was obtained in A.E.C. establishments, such as Oak Ridge, Argonne, Los Alamos, and Hanford, and much of this experience is now being applied to civilian atomic projects, such as the Indian Point nuclear power station of the Consolidated Edison Company in New York and the Dresden nuclear power station of the Commonwealth Edison Company in Illinois. The following five points are to-day considered of paramount importance in fuel element design :—(1) Proper geometry with high surface-to-volume ratio ; (2) simplicity of form combined with maximum mechanical stability ; (3) greatest degree of self-support with least amount of structural material ; (4) maximum corrosion resistance obtained by alloying or by cladding ; (5) low parasite capture cross section and absence of poison-forming tendencies.

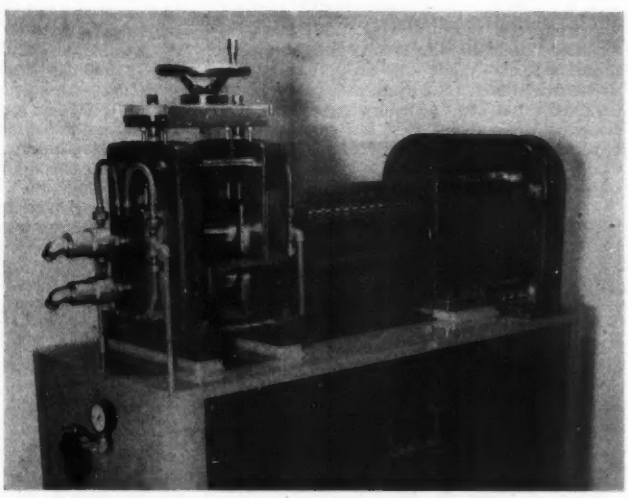


Fig. 2—6in wide, two-high rolling mill prior to installation in glovebox enclosure

To date, fuel element development has concentrated on plate and cylindrical designs, and this article is primarily concerned with flat shapes.

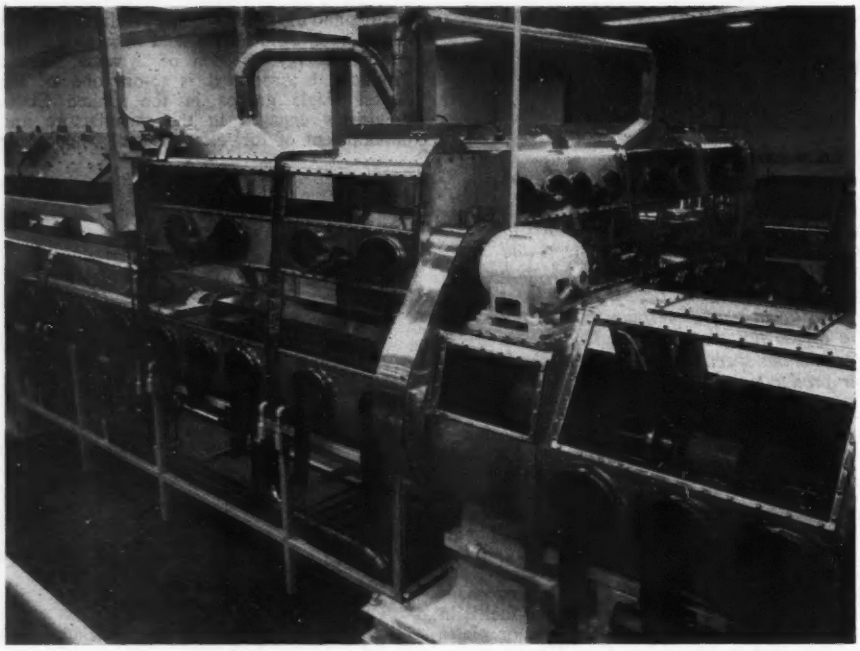


Fig. 4—Rolling mill installation within stainless steel and glass glovebox at the Los Alamos Scientific Laboratory

The two configurations shown in Fig. 3 may be considered to be the basic designs of flat plate elements. Such wide, thin plates give maximum heat transfer surface per unit volume of fuel; however, they may become mechanically unstable, and the resulting vibrations or distortions can produce failure of the elements. Applying a small degree of curvature to the plates improves the stability of the assembly, and this approach has been taken in the elements for such units as the Materials Testing Reactor (MTR) at the National Reactor Testing Station in Idaho and the "CP-5" research reactor at the Argonne National Laboratory.

Basic Materials

The fabrication of fuel elements involves two major groups of materials. The first group includes natural uranium, enriched uranium, plutonium and thorium, while the latter group includes aluminium alloys, zirconium alloys and stainless steel. While the early reactors constructed by the A.E.C. using natural or slightly enriched uranium generally employed slug elements, more recent solid fuel reactor designs have replaced the "canned" uranium slugs by clad plates having a uranium alloy core and a bonded sheath of corrosion-resistant material, such as aluminium-tin, zirconium-tin or stainless steel. Another design now becoming popular is the dispersion fuel element having fine particles of the fuel metal or its oxide dispersed in a metallic or ceramic matrix, such as UO_2 in aluminium or in beryllia. Aluminium alloy-clad fuel elements are limited to low-temperature applications up to about 400 deg. Fah. maximum. Zirconium alloy-clad units may operate up to about 1000 deg. Fah. maximum, while stainless steel-clad elements could stand temperatures close to 1200 deg. Fah. However, such iron-base alloys have the disadvantage of a high thermal neutron absorption cross section, which has to be compensated for by using enriched fuel.

To cope with even higher temperatures, molybdenum and its alloys are likely to enter the fuel element picture. The Russian "Atomic Power Station No. 1" reactor, which generates about 30MW of heat, employs 5 per cent uranium 235 enriched hollow fuel element cylinders enclosed in a metal jacket. It is believed that an alloy of uranium and molybdenum is used in this design, which, incidentally, shows excellent heat transfer characteristics.

Depending upon the design of the reactor, fuel elements may be required in a wide variety of shapes and configurations, including (*a*) flat, curved and corrugated plates; (*b*) solid and hollow slugs; (*c*) rods; (*d*) tubes; (*e*) plate, slug, rod and tube assemblies; (*f*) wire; (*g*) wafers; (*h*) pellets and spheres; (*i*) foil. In addition to containing uranium, thorium and plutonium in metallic or compound form, fuel elements may involve a wide range of non-fissionable materials, including stainless steel, "Nichrome," aluminium, magnesium, zirconium, beryllium, titanium, nickel, chromium, copper, silicon, niobium and molybdenum, and their alloys. The latter materials are employed either in conjunction with the fissionable materials as an alloy, a powder metallurgical compound or a mixture in the fuel core, or as a cladding for the fuel to protect it from corrosive attack and to contain the fission products.

Workability of Materials

From a fabricating point of view, the manufacturer of fuel elements is very much concerned with the mechanical properties of the materials employed. An idea of the relative workability of the principal fuel element materials may be obtained from the following data which relate to annealed metal at room temperature :—

Material	Ultimate tensile strength, lb per sq. in	Yield strength (0·2 per cent offset), lb per sq. in	Elongation in 2in (per cent)	Young's modulus (lb per sq. in)
Uranium	120,000	52,000	11	26×10^6
Thorium (bomb-reduced)	33,000	23,000	26	11×10^6
Plutonium	Classified			
Aluminium (2S alloy)	13,000	5,000	45	10×10^6
18–8 stainless steel (type 302)	85,000	40,000	55	29×10^6
Zirconium (crystal-bar+2·5 per cent tin)	46,000	35,000	40	14×10^6

The majority of uranium fabrication is performed in the alpha phase and can be accomplished without difficulty. Initial ingot or billet breakdown rolling is generally done at elevated temperatures up to about 1100 deg. Fah. maximum. Finish rolling of sheet is usually performed on four-high mill equipment, 90 per cent cold reduction being possible without intermediate annealing.

Thorium metal of good quality is extremely ductile and may readily be hot rolled. Castings show a tendency toward intergranular cracking if cold worked directly and are therefore hot

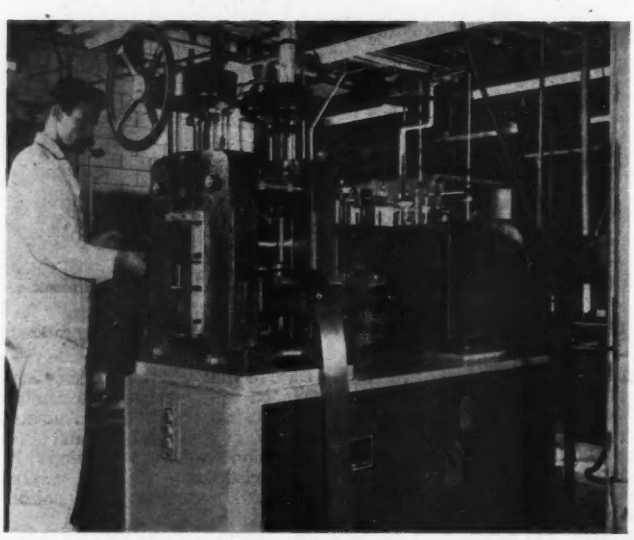


Fig. 5—Four-high cold-finish rolling of strip material at the Atomic Energy Division of Sylvania Electric Products in Bayside, New York

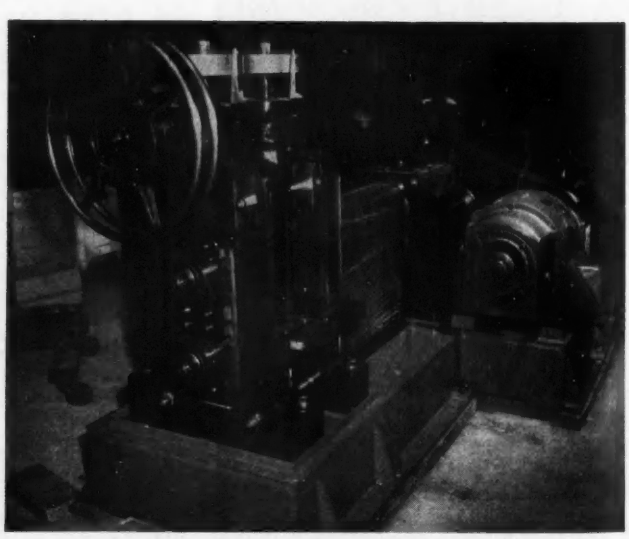


Fig. 6—2¼in and 8in by 8in, two-high/four-high combination rolling mill with 30 h.p., d.c. drive installed at the Hanford Works of the General Electric Company

worked initially to break up the cast grain structure. Subsequently, the metal is highly malleable, and it is possible to obtain as much as 99 per cent cold reduction without intermediate annealing. The ultimate tensile strength of thorium is increased from 33,000 lb to about 78,000 lb per square inch by subjecting the metal to 90 per cent cold work. Although thorium is an alpha emitter, the processed metal has a relatively low activity level and is normally handled without protective clothing or shielding.

Both aluminium alloys and stainless steels are readily workable and allow total cold reduction of up to 90 per cent to be obtained. Zirconium and most of its alloys have adequate ductility at room temperature and permit a satisfactory degree of cold rolling. Total reduction between anneals of up to 80 per cent are feasible with pure zirconium and up to 50 per cent with an alloy containing 2½ per cent tin.

Plutonium Fabrication

Although plutonium 239 is not among the most radioactive materials, it has to be handled with extreme care, and the A.E.C. has established very stringent health protection requirements for its installations. The alpha particle has a relatively low penetration ability and can be stopped by a comparatively thin shield, such as the "Neoprene" gloves employed in glovebox enclosures. The greatest danger at a laboratory or processing works handling plutonium is the inhalation of plutonium-bearing dust. Plutonium entering the body is deposited primarily in the bones and is excreted very slowly; the time required for man to excrete one-half his body burden is estimated to be about 100 years. According to current knowledge the maximum permissible total body burden has been set at 0·5 microgramme, and works ventilation requirements are such that the air must not show a plutonium dust content greater than 7×10^{-4} microgrammes per cubic metre of air.

Much of the original plutonium fabrication work was done at the Los Alamos Scientific Laboratory of the University of California at Los Alamos, New Mexico. The extent to which this laboratory went in providing proper enclosures and ventilation is well illustrated in Figs. 2 and 4, respectively showing the original commerically available 6in wide, two-high rolling mill and its ultimate "enclosed" installation at Los Alamos. The rolling mill forms part of an experimental fabricating facility, including other rolling, swaging, wire drawing and annealing equipment. It is fed and operated through the long rubber gauntlets which can be seen at the front of the stainless steel hoods. If the workpieces become too long to be handled inside the enclosure, extension boxes can be added in line with the mill pass line.

A salt bath furnace is available for heating workpieces inside the enclosure, and there is a small motorised crane for handling purposes. The rolling mill is driven by a 7½ h.p. variable-speed drive situated outside the enclosure. It is equipped with a single handwheel screwdown, continuously circulating oil lubrication and needle roller bearings on the roll necks. Most parts may be removed from the enclosure by transfer into plastic bags temporarily attached to the enclosure. Subsequently the bags are sealed off and packaged for shipment to the burial grounds.

Rolling Mill Practice

Since at this initial stage the quantities involved in individual fuel element fabrication orders are likely to be small, most American companies entering this field desire to limit their capital investment as much as possible. Thus, while conventional metal processing practice may call for a two-high hot breakdown mill, a two-high cold intermediate mill, and a four-high cold sheet finishing mill, the fabricators of fuel elements to-day generally prefer to use a single machine capable of handling their entire rolling needs, from the initial ingot to the final sheet. Hence there arose a need for a precision mill capable of the widest possible range of ingot, bar, rod and sheet reduction, available at a price within reach of a limited budget and compactly designed to fit into the often restricted space of nuclear works and laboratories. The two-high/four-high combination rolling mill has been developed to fill this need, and such an installation, at the Babcock and Wilcox Nuclear Facilities Works in Lynchburg, Virginia, is arranged for the two-high hot breakdown rolling of fuel material billets. When functioning as conventional two-high units such mills have relatively large work rolls for breakdown rolling of ingots and bars, reduction of strip requiring high lustre, and for skin passing of annealed strip. Apart from power considerations, the determining factor for breakdown rolling is generally the maximum draught per pass that can be taken with the material entering the rolls unassisted.

The work rolls should be of relatively large diameter also for skin pass rolling of annealed strip, when a reduction of only about 1½ per cent is

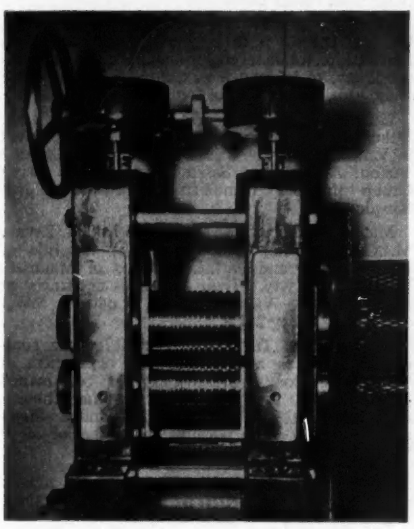


Fig. 7—8in wide combination rolling mill set up for the two-high hot rolling of rounds from ½in to 3/32in diameter

usually desired. Such rolls are also advantageous for reducing strip with little or no lubricant so as to obtain a bright and highly burnished surface finish. This lustre effect is directly due to the fact that the larger the work roll diameter the greater the amount of slipping between roll surface and material.

The four-high arrangement of an 8in wide combination rolling mill installed at the Atomic Energy Division of Sylvania Electric Products, Incorporated, at Bayside, New York, is illustrated in Fig. 5. Work rolls ranging from 1½in down to ¾in diameter may be used in this machine, facilitating the reduction of strip thickness to less than 0·001in gauge. The unit is driven at speeds ranging from about 30ft to 185ft per minute by a 15 h.p. motor mounted in the base. The "Meehanite" mill housings have a cross-sectional area of 120 square inches, and the roll neck bearings can sustain a maximum separating force of 150,000 lb.

A considerably heavier combination rolling mill installed at the Hanford Atomic Products Operation at Richland, Washington, is illustrated in Fig. 6. This machine has 8in diameter backup rolls and can use work rolls within a 2½in to ¾in diameter range. The cast steel mill housings have a cross-sectional area of 224 square inches and the roll neck bearings can sustain a maximum separating force of 300,000 lb. The 30 h.p. variable-speed mill drive gives constant horsepower over a 25ft to 75ft per minute rolling speed range.

In the fabrication of fuel elements of other than flat plate design grooved rolls are frequently employed in the combination mill to obtain the cylindrical and other shapes required. The sizes of individual fuel slugs are generally quite small, and the ¾in diameter by 6in long uranium slugs used in the Sodium Reactor Experiment (SRE) facility of North American Aviation, Incorporated, are representative of current American practice in this respect. Fig. 7 shows an 8in wide combination mill installed at the Aircraft Nuclear Propulsion Department of the General Electric Company set up for the processing of such rounds.

(*To be continued*)

Lightweight High-Altitude Research Missile

The University of Maryland and the Republic Aviation Corporation have jointly announced the first flight of a new extremely light high-altitude research missile being used in obtaining data for the development of space vehicles. The first flight of the new rocket lasted 5·6 minutes. In this time the missile climbed 80 miles and relayed measurements of the primary cosmic radiation, the temperatures and the spin of the rocket and the acceleration experienced by its internal equipment. The rocket firing was the first of a series of correlated launchings to be made from different areas around the earth to probe the ionosphere. Data obtained from this and subsequent firings will be used by a group of scientists, headed by Dr. S. Fred Singer, of the University of Maryland, to obtain an integrated picture of the upper atmosphere. Named "Terrapin" after the University of Maryland's mascot, the two-stage rocket is less than 15ft long, 6¼in in diameter at its thickest point, and weighs only 224 lb. It was designed and produced by the Guided Missiles Division of Republic in Mineola, Long Island, New York.

A solid propellant rocket motor fired the "Terrapin" to 10,000ft in six seconds at a speed of 1900 m.p.h. At that altitude the first stage of the missile separated from the second stage, which coasted another 30,000ft higher. Then the second-stage motor shot the "Terrapin" to 50,000ft at a maximum speed of Mach 5·8, or about 3800 m.p.h. The missile coasted the rest of the way to peak altitude. At maximum velocity the rocket experienced temperatures in excess of 1000 deg. Fah. It was fired from the proving ground of the National Advisory Committee for Aeronautics at Wallops Island, Virginia. Preliminary design has now been completed of a third-stage rocket for the "Terrapin," which will enable it to climb to altitudes 200 miles and higher. The research missile and its collapsible launching gear were especially designed for the upper atmosphere research programme of the Department of Defence, which is administered by the University of Maryland. It carries special miniaturised instrumentation weighing only 6 lb, which was designed at the University.

The instruments, which are housed in the "warhead" of the missile, make use of several new electronic principles, including printed circuits, an all-transistorised telemetering system, a Geiger counter to measure radiation and a new design of transmitter. Special protective devices were designed into both the rocket and instruments to shield the sensitive equipment from the intense heat. The first-stage rocket motor was designed by the Allegheny Ballistics Laboratory in conjunction with the U.S. Navy Bureau of Ordnance. The second-stage rocket motor was designed by the Thiokol Corporation in conjunction with the Redstone Division of the U.S. Army Ordnance Corps. The Republic Aviation Corporation was awarded the "Terrapin" contract as the result of a design competition for the best-performing missile at the lowest cost.

Packaged Nuclear Reactors

A 1000kW transportable nuclear reactor which weighs 24,000 lb and can be assembled and put into operation in three days is being built by the Glenn L. Martin Company in Baltimore, Maryland, for service in Dominica. The whole plant, including the nuclear fuel generating set and maintenance building, is packed in eight pods (the largest being 9ft by 9ft by 30ft) of structural aluminium, which later form the permanent housing for the plant. The fuel charge consists of over 5000 tubular elements of slightly enriched uranium and the reactor is water cooled.

Personal and Business

Appointments

MR. JOSEPH SAMUELS has been appointed a director of Winston Electronics, Ltd., Shepperton, Middlesex.

MR. BRIAN MAXWELL-MULLER has joined the technical sales department of Smiths Aircraft Instruments, Ltd.

MR. B. C. KIRK has been appointed chairman, and Mr. V. G. Eyre, managing director, of Monks and Crane, Ltd.

THE DAIMLER COMPANY, Ltd., announces the appointment of Mr. Arthur Griffiths as director and general manager.

DR. A. M. UTTLEY has been appointed superintendent of the control mechanisms and electronics division of the National Physical Laboratory, Teddington.

MR. G. O. MCLEAN, M.I.E.E., has relinquished his position as chief engineer of the South Western Electricity Board in order to practise as an engineering and industrial consultant.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., states that Mr. J. L. Mease, A.M.I.Mech.E., has been appointed an additional assistant superintendent at the Sheffield works.

MR. W. F. RANDALL, M.I.E.E., managing director of the metals group of the Telegraph Construction and Maintenance Company, Ltd., has been appointed a director of Submarine Cables, Ltd.

THE NATIONAL COAL BOARD states that Mr. L. R. Milligan has been invited to accept the post of industrial relations director of the Scottish Divisional Board in succession to Mr. J. Barbour, who has retired.

WELDING SUPERVISION, Ltd., states that Mr. C. C. Bates, manager of the company, has been appointed a director. He will also be concerned with the welding activities of the parent company, Costain-John Brown, Ltd.

MR. J. W. BUTLER has been appointed assistant director of the Joint Iron Council, the Council of Iron Producers, and the Council of Ironfoundry Associations. Mr. D. L. Farrant has been appointed secretary of each of these bodies.

METROPOLITAN-VICKERS ELECTRICAL EXPORT COMPANY, Ltd., has announced the following appointments :—Mr. H. F. Bibby, A.M.I.Mech.E., A.M.I.E.E., assistant general manager ; Mr. C. H. de Nordwall, M.I.E.E., manager of the American division.

THE BRITISH TRANSPORT COMMISSION has announced the following appointments : Mr. S. H. Locke, house superintendent (general staff) ; Mr. E. M. Eustace, head of section (metals), headquarters stores department ; Mr. S. R. Triplett, deputy mining engineer, British Railways' central staff.

SENTINEL (SHREWSBURY), Ltd., announces the appointment to the board of Mr. J. D. Pearson and Mr. W. T. Gill. Mr. Pearson is the deputy chairman, and Mr. Gill the financial director, of Rolls-Royce, Ltd. The new appointments follow the acquisition by Rolls-Royce, Ltd., of a controlling interest in Sentinel (Shrewsbury), Ltd.

BABCOCK AND WILCOX, Ltd., has announced the retirement of Captain William Gregson, R.N.R., M.I.Mech.E., from the position of chief engineer and manager of the marine department. He will continue to serve as a director of the company and as technical adviser to Spencer-Bonecourt-Clarkson, Ltd. Mr. Wilfred R. Harvey, M.I.Mar.E., has been appointed manager of the marine department. He has been deputy manager since 1941.

Business Announcements

PLESSEY INTERNATIONAL, Ltd., has opened a branch office at Singel 160, Amsterdam.

MARCONI INSTRUMENTS, Ltd., has moved its Midland office to 24, The Parade, Leamington Spa.

MR. W. LATTA, sales director of Rhodes, Brydon and Youatt, Ltd., Stockport, is visiting South Africa.

J. H. FENNER AND CO., Ltd., states that production has now started in its new engineering shops at Marfleet, Hull.

PHILIPS ELECTRICAL, Ltd., states that its ELA (electro-acoustic) division has been merged with the musical equipment department.

THE DORMAN SPRAYER COMPANY, Ltd., Ditton Walk, Cambridge, has taken over the spare parts and servicing business of the Watson Sprayer Company, Ltd.

MODERN MACHINE TOOLS, Ltd., Broadgate House, Coventry, is now the stockist and distributor of the lathes and bench presses made by Smart and Brown (Machine Tools), Ltd.

BRITISH TYRE AND RUBBER COMPANY, Ltd., Herga House, Vincent Square, London, S.W.1, has acquired a site at Farington, Lancs, in order to expand its manufacturing facilities.

THE OWEN ORGANISATION states that two of its member firms, Salopian Engineers, Ltd., and Kenneth Hudson and Son, Ltd., are now concerned solely with design and marketing.

THE NATIONAL GAS AND OIL ENGINE COMPANY, Ltd., has made agreements with Alan Muntz and Co., Ltd., for the manufacture under licence of the "Pescara" free piston engine system.

LANCASHIRE DYNAMO NEVELIN, Ltd., is the title of a company incorporating Nevelin Electric Company, Ltd., and Lancashire Dynamo Switchgear, Ltd. Its works are at Hurst Green, Oxted, Surrey (telephone, Oxted 1450).

CUMMINS ENGINE COMPANY, Inc., Columbus, Indiana, U.S.A., is to establish a plant at Shotts, Lanarkshire, for diesel engine manufacture. A British subsidiary, to be known as Cummins Engine Company, Ltd., is in process of formation.

BRUSH GROUP SALES (WESTERN CANADA), Ltd., is the title of a company which has been incorporated in Vancouver for the sale in British Columbia, the Yukon, Alberta and Saskatchewan, of all Brush Group products manufactured in the United Kingdom.

MR. J. A. POSFORD, M.I.C.E., and MR. R. PAVRY, M.I.C.E., are now practising under the title of Posford, Pavry and Partners, instead of Maunsell, Posford and Pavry. Their address is unchanged at Abbey House, Victoria Street, London, S.W.1 (telephone, Abbey 2115).

MAJOR P. L. TEED, deputy chief of the aeronautical research and development department at Vickers-Armstrongs (Aircraft), Ltd., has been invited to give lectures at Wright Field, the Massachusetts Institute of Technology and the United States research laboratory at Washington, on the subject of "Fatigue of Aircraft."

Contracts

THE BRITISH INDIA STEAM NAVIGATION COMPANY, Ltd., has placed an order for five medium sized cargo ships of 6500 tons deadweight with Harland and Wolff, Ltd. The ships will be built at the company's Govan yard.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., Trafford Park, Manchester, has received from the New Zealand State Hydro-Electric Department an order for transformers totalling 80,000kVA in capacity. They are to be installed at Wairakei power station, which is the first station in the country to use natural steam obtained by boring beneath the surface of the earth. The new transformers will consist of seven single-phase units, forming two 40,000kVA, three-phase groups, with one spare unit. The voltage ratio is 11/220kV, and off-circuit tappings will be provided for 225kV and 230kV on the h.v. side. The transformers will be cooled by pumping the oil through oil-to-water heat exchangers.

STANDARD TELEPHONES AND CABLES, Ltd., has received a contract from the Portuguese Administration, Administraçao Geral Dos Correios, Telégrafos E Telefones (CTT), for the provision of a telecommunications network between Lisbon and Oporto and other localities in the presidency. Manufacture of the equipment will be shared between Standard Telephones and Cables, Ltd., and its associates, Standard Electrica Lisbon, and will proceed concurrently in Great Britain and Portugal. Two cables are being provided over a route of some 400km, consisting of a six-tube coaxial cable, with a parallel cable for short-distance audio and carrier-frequency circuits. The network will incorporate a "Standard" multi-channel carrier telephone system with a capacity of 960 two-way telephone circuits over two tubes of the six-tube coaxial cable. The main stations will be located at Lisbon and Oporto.

Miscellanea

AUTOMATION, EDUCATION AND TRAINING.—A one-day conference on "Automation, Education and Training" is to be held at the Royal Festival Hall, London, S.E.1, on Tuesday, December 4th, beginning at 10 a.m. It is being organised by the British Association for Commercial and Industrial Education. At the morning session, three papers dealing with "Automation in Perspective," will be presented, and in the afternoon there is to be a general discussion on the main considerations for education and training.

INDUSTRIAL TRIODE VALVES.—Three new triode valves, intended mainly for use in industrial heating equipment, have been developed by The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2. They have thoriated filaments and anode dissipations of 5kW, 10kW and 20kW, respectively. Water-cooled versions of the 10kW and 20kW valves are also available.

TRIODE FOR INDUSTRIAL R.F. GENERATORS.—The "TY7-6000" valve is a new Mullard triode specially developed for use in industrial r.f. generators. It is designed for an output of 6kW at frequencies up to 50Mc/s and anode voltages up to 7kV. There are two versions, the "TY7-6000 A," which is designed for forced air cooling, and the "TY7-6000 W," which is water-cooled. They have directly-heated thoriated tungsten filaments and external anodes.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—On November 6th, Mr. J. G. Annan read a paper entitled "Operation of a Modern Petroleum Refinery" before the Institution of Engineers and Shipbuilders in Scotland. The paper describes the operation of a modern oil refinery of the kind constructed in Great Britain during recent years. A typical crude oil is considered and the various stages of refining are described, while problems of blending and storage are discussed, and the importance of avoiding corrosion in the plant emphasised.

DIESEL ENGINEERS AND USERS ASSOCIATION.—At a meeting of the Diesel Engineers and Users Association, held on November 15th, Mr. J. S. Tritton read a paper entitled "The Special Requirements of Diesel Engines for Rail Traction." The paper discusses restrictions on design and space and the general requirements of railway service, and briefly touches upon diesel shunters, railcars and main line locomotives before going on to consider essential characteristics. These concern questions relating to reliability, maintenance, various forms of transmission and economics. The latter section considers first cost, relative operating costs and percentage availability. Load factors and classification questions are mentioned as well as items such as engine rating and acceptance tests, and the paper concludes with a consideration of design trends touching upon crankshafts, pistons, cylinder heads, bearings and supercharging.

ROYAL SOCIETY MEDALS.—The following awards of medals have been made by the president and the council of the Royal Society :—The Copley Medal, to Professor P. M. S. Blackett, F.R.S., Professor of Physics at the Imperial College of Science and Technology, London, for his outstanding studies of cosmic ray showers and heavy mesons and in the field of palæomagnetism ; the Rumford Medal, to Dr. F. P. Bowden, F.R.S., Reader in Physical Chemistry in the University of Cambridge, for his distinguished work on the nature of friction ; the Davy Medal, to Professor R. D. Haworth, F.R.S., Firth Professor of Chemistry and Head of the Chemistry Department in the University of Sheffield, for his distinguished contributions to the chemistry of natural products, particularly those containing heterocyclic systems ; the Darwin Medal, to Dr. J. S. Huxley, F.R.S., for his distinguished contributions to the study and theory of evolution ; the Hughes Medal, to Viscount Cherwell, C.H., P.C., F.R.S., lately Professor of Experimental Philosophy in the University of Oxford, for his distinguished work in many fields.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—On November 16th, before the North East Coast Institution of Engineers and Shipbuilders, Mr. C. D. Boadle read a paper with the title "Some Safety Considerations of Nuclear Power Reactors." The paper states that the large-scale generation of electrical power from nuclear energy introduces a number of new hazards derived mainly from the simultaneous production of large amounts of radioactive fission products, which must not be released in an uncontrolled manner. Nuclear reactors, the paper mentions, have characteristics unlike other power producers, some provide self-regulating features, while others provide the means of rapid power surges capable of causing serious damage unless in charge of a control and monitoring system. Most reactors must be completely contained within a gas-tight building to ensure that radioactive materials will not be discharged following an accident. The nature, causes and effects of a mishap are discussed, including incidents arising from an uncontrolled power excursion, failure of main coolant flow and incidents involving the rupture of the reactor container. The paper goes on to note the protective equipment of a reactor and the main current designs of reactor and concludes by discussing certain aspects of the more advanced systems now under consideration.

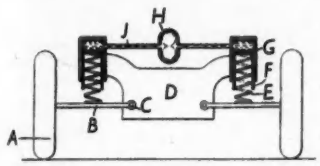
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

ROAD TRANSPORT

758,761. April 2, 1954.—ANTI-ROLLING DEVICE FOR VEHICLES, Societe Anonyme Andre Citroen, 117 to 167, Quai de Javel, Paris (Seine), France.

The invention relates to vehicles having suspension systems comprising wheel supporting members which are sprung with respect to the chassis frame by springs or pneumatic cushioning devices. It has



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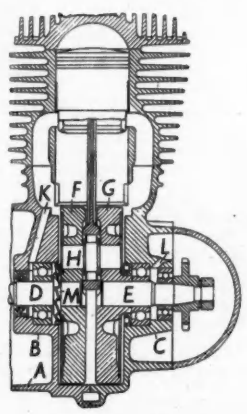
for its object to provide means for restoring the position of the chassis frame with respect to the wheel supporting members whenever a curve or a hole in the road causes an inclination of the frame with respect to the wheel supporting members. The drawing shows the stabilising device on a set of vehicle wheels. The wheels *A* are mounted on the arms *B* connected at *C* to the chassis frame *D*. Springs *E* attached to the arms bear on the chassis frame *D* by means of the pistons *F*, which slide in the cylinders *G*. These cylinders contain a liquid and are connected to a pump *H* by a piping *J*. Liquid is transferred from one cylinder to the other under the control of a distributor which is operated by a predetermined movement of the wheel supporting members relatively to the chassis frame, the arrangement being such that liquid is removed from the cylinder on the less loaded side and delivered to the cylinder on the heavier loaded side of the vehicle. Various applications of the invention and a description of a slide valve for regulating the flow of liquid are also given in the specification.—*October* 10, 1956.

INTERNAL COMBUSTION ENGINES

758,654. July 10, 1953.—TWO-STROKE CYCLE ENGINES, The Birmingham Small Arms Company, Ltd., Armoury Road, Small Heath, Birmingham (*Inventor: Edgar Gerald Bayliss.*)

The invention relates to internal combustion engines of the two-stroke cycle type having petroil lubrication, its object being to provide an improved method of and means for lubricating the crankshaft bearings in engines of the kind specified. As shown



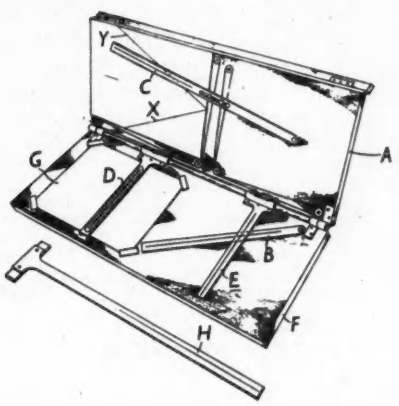
No. 758,654

by the drawing a crankcase *A* of a single-cylinder internal combustion engine has formed therein two bearing housings *B* and *C*. Supported by ball bearings is a crankshaft formed in two parts *D* and *E*. Mounted on the crankshaft is a flywheel constructed in two separate parts *F* and *G*, which are retained together by a pin *H* eccentrically mounted. The two parts of the flywheel have a gap between them. Connected to the pin *H* is the big-end of the piston connecting-rod. Formed in the housing *B* of the crankcase and extending substantially vertically upwards from or near the outer end of the ball bearing is a passage *K* leading into the transfer port of the engine, whilst in the housing *C* a second passage *L* is also formed. Mounted on the face of the part *F* of the flywheel nearest the passage *K*, and thus in proximity to the bearing, is a centrifugal fan *M*. The fan has a series of blades inclined to the axis of the crankshaft. The fan creates a suction or partial vacuum at the inner end of the bearing, thereby inducing a flow of lubricant laden mixture from the transfer port down the passage *K*, through the bearing and on to the fan blades from where it is discharged on to the crankcase by centrifugal force. As the lubricant-laden mixture passes through the bearings it ensures efficient lubrication. In an alternative arrangement, a second centrifugal fan may be mounted on the face of the part *G* of the flywheel in proximity to the opposite bearing to induce a flow down the passage *L* and through the bearing. However, the use of a second fan is not essential since that bearing is usually adequately lubricated by oil mist in the crankcase which can drain down the passage *L*. —*October* 10, 1956.

DRAWING-OFFICE EQUIPMENT

757,694. May 22, 1952.—MAKING PERSPECTIVE DRAWINGS, Metropolitan-Vickers Electrical Company, Ltd., St. Paul's Corner, 1–3, St. Paul's Churchyard, London, E.C.4. (*Inventor: Eric Vincent Scandrett.*)

The invention relates to apparatus for producing perspective drawings. A plan and elevation of the object to be depicted are first cut from a normal engineering drawing, and the part bearing the plan view is fixed to the upper board *A* with adhesive tape,



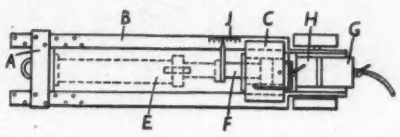
No. 757,694

in such a position that the elevation could be seen by looking in the direction of one of the reference lines *X* or *Y*. If *X* is chosen, then the lower radial arm *B* is clipped into its left-hand socket. If, however, the direction *Y* is chosen, then the right-hand socket is used. Moving the radial arm *C* so that it becomes horizontal now brings the two sliders *D* and *E* to their mid-positions. The elevation drawing is now fixed in position on the lower board *F* so that the desired amount of " bird's-eye viewing " is obtained, when seen from the pivot of the lower radial arm B, and so that the distance between any point on the elevation and the line on the slider *E* is the same as the distance between the same point seen in the plan, and the chosen reference line. The drawing sheet *G* is now fixed to the lower board *F* as shown, and the perspective view is constructed on this sheet, by locating points and suitably joining them. The upper radial arm *C* is moved so that its control line lies over the required point, as it is represented in the plan. This movement automatically brings the two sliders *D* and *E* into their appropriate positions. The lower radial arm *B* is then moved beneath the right-hand slider *E* so that its central line lies over the required point as it is represented in the elevation. The tee square *H* is now held against the left-hand edge of the lower board *F*, and is placed so that its inscribed line lies over the intersection of the lines on the right-hand slider *E* and the lower radial arm *B*. The required point is now located on the drawing sheet by placing a pencil point against the tee square and marking through the slot in the left-hand slider *D*. —*September* 26, 1956.

MINING ENGINEERING

759,620. October 2, 1953.—APPARATUS FOR TESTING PIT PROPS, Demag Aktiengesellschaft, 64, Werthauser Strasse (22A), Duisburg, Germany.

The invention is based on the knowledge that a substantial percentage of the iron props in use in mines cannot be guaranteed to be strong enough and has among its objects to avoid this disadvantage by simple means. As shown in the drawing, the apparatus consists of a cross-head *A* connecting two tie-rods *B*, and at the opposite ends of the tie-rods to those connected by the cross-head a cross member *C*. On the cross member is mounted a press cylinder. As illustrated, the prop *E* to be tested



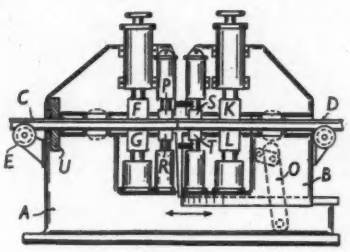
No. 759,620

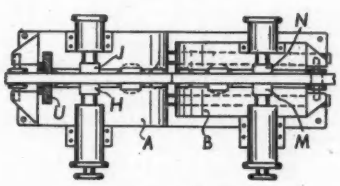
is clamped between the cross-head *A* and a plunger *F* for sliding movement in the cylinder. On switching-on a compressed air motor *G*, pressure liquid is pumped through a pump *H* into the cylinder until the pressure applied, which may be read on a pressure gauge has reached that to which the prop is tested. The extent of compression of the prop at determined pressures is read from a graduated scale *J* so that it is possible easily and quickly to judge the general condition of the prop by its reaction to the pressure applied.—*October* 24, 1956.

RAILWAY ENGINEERING

760,000. December 23, 1954.—ELECTRICAL FLASH-WELDING MACHINES FOR WELDING RAILS, H. A. Schlatter A.G., Seestrasse 121, Zollikon, Zürich, Switzerland.

The invention is concerned with improvements in flash-welding machines for rails. It provides a machine in which for each of the rails to be welded together there are provided two pairs of clamping members which grip perpendicularly to each other, the one member of each pair acting as an adjustable





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stop to determine the position of the rail and the other acting as a pressure member to press the rail against the stop. Referring to the drawing, it will be seen that the welding machine includes a massive base *A* which carries a carriage *B* for reciprocating movement in the direction of the arrows shown. By way of example, a pair of railway rails *C* and *D* are shown in the machine. The left rail *C* is guided into the machine by a roller *E* mounted on the base and having a pair of outer guide flanges, the rail being clamped between a pair of members *F* and *G*, on the one hand, and a pair of members *H* and *J*, on the other hand, the mechanism for moving these members being mounted on the base. The rail *D* is moved into the machine from the right and is guided by a roller identical with roller *E*. This rail is clamped between members *K* and *L* and *M* and *N*. A lever *O* is connected to the carriage for reciprocating it, this lever being operated by a piston. The carriage *B* is reciprocated, together with the rail *D*, during the welding process with respect to the stationary rail *C*. In addition to the arrangement for clamping the rails, there is provided for each rail a pair of contacts for feeding electrical current to the rails, one pair of these contacts, *P* and *R*, being associated with the rail *C*, and another pair, *S* and *T*, with the rail *D*. The contacts of each pair are urged toward each other with the same pressure and engage opposite faces of the rail. Between the left roller *E* and the members *H* and *J* is a means for removing flash and upset, this being indicated at *U*.—*October* 24, 1956.

Catalogues and Brochures

COAL UTILISATION COUNCIL, 3, Upper Belgrave Street, London S.W.1.—Catalogue giving details of domestic solid fuel appliances.

LEXINGTON PRODUCTS, Ltd., 2, Lexington Street, London, W.C.2.—A leaflet giving information on the "Lexite" fluorescent inspection lamp.

NEWALL GROUP SALES, Ltd., Peterborough.—A catalogue illustrating "OMT" optical inspection equipment and optical measuring equipment.

GIBBONS BROTHERS, Ltd., P.O. Box 19, Dibdale, Dudley, Worcs.—Leaflet illustrating bogie hearth furnaces, gas, oil or coal fired, for stress relieving, annealing and normalising.

KODAK, Ltd., Industrial Sales Division, Kodak House, Kingsway, London, W.C.2.—Illustrated catalogue of X-ray materials, chemicals and equipment. A separate price list is included.

HACKBRIDGE AND HEWITTIC ELECTRIC COMPANY, Ltd., Walton-on-Thames, Surrey.—Leaflet illustrating transformers and rectifiers and their uses in industry, science and the armed Forces.

TAYLOR STOKER COMPANY, Ltd., 189–191, Drummond Street, Euston, London, N.W.1.—Leaflet describing several types of "Lo-Hed" electrical hoists available for various kinds of industrial use.

THE ELECTRIC CONSTRUCTION COMPANY, Ltd., Bushbury Engineering Works, Wolverhampton.—Booklet illustrating a range of power equipment for telecommunications (alternating current).

WOLF ELECTRIC TOOLS, Ltd., Pioneer Works, Hanger Lane, London, W.5.—Leaflet illustrating the application of home constructor portable electric tools in rehabilitation and occupational therapy.

HUNTING GEOPHYSICS, Ltd., 6, Elstree Way, Boreham Wood, Herts.—Illustrated leaflet giving details of a mineral prospecting service from the air. The instruments used are described and the method of operation explained.

LANCASHIRE DYNAMO AND CRYPTO, Ltd., Trafford Park, Manchester, 17.—Pamphlet entitled "L.D.C. Motors for Machine Tools," illustrating motors ranging from ¼ h.p., T.E., d.c., servo motor to ag. 50 h.p. S.C.R. motor.

ARMATURE MANUFACTURING COMPANY, Middleton Road, Oldham, Lancs.—Leaflet giving details of electrical workshop equipment, including electrical test benches, ball race extractors, puller presses, magnetisers, &c.

ALLEN WEST AND CO., Ltd., Brighton, 7.—Booklet giving details of standard ranges of motor starters and oil-break distribution switchgear and examples of some of their many applications within the fields of industrial traction and marine duties.

THE TELEGRAPH CONSTRUCTION AND MAINTENANCE COMPANY, Ltd., Mercury House, Theobald's Road, London, W.C.1.—Pamphlet describing the various types of joints made with the "Telcon" PB joint boxes. A list of accessories and tubing is included.

RENOLD CHAINS, Ltd., Renold House, Wythenshawe, Manchester. Brochure illustrating a selection of chain applications in many varied branches of industry. A section is included showing typical examples of the standard range of products available.

FOSTER TRANSFORMERS, Ltd., South Wimbledon, London, S.W.19.—Several lists of various types of transformers, giving dimensions, weight, price, &c.; they include "U" type Neon transformer, standard ignition transformer, mining type transformer.

BRITISH TRANSPORT COMMISSION, 222, Marylebone Road, London, N.W.1.—A new British Road Services brochure containing information about contract hire services provided by British Road Services (Contracts), Ltd., and British Road Services (Pickfords), Ltd.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Wed., Nov. 28th.—BRIGHTON, HOVE AND DISTRICT BRANCH: New Imperial Hotel, First Avenue, Hove, "Motor Control Gear," R. F. Mathieson, 7.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

To-day, Nov. 23rd.—SCOTTISH SECTION: Department of Natural Philosophy, The University, Edinburgh, "Information Theory," L. C. Stenning, P. Jones and P. Holroyd, 7 p.m.
Wed., Nov. 28th.—School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Colour Television," G. N. Patchett, 6.30 p.m.
Wed., Dec. 5th.—S. WALES SECTION: College of Technology and Commerce, Cathays Park, Cardiff, "Voltage Stabilisation," F. A. Benson, 6.30 p.m.

BRITISH INTERPLANETARY SOCIETY

Sat., Dec. 1st.—Caxton Hall, Westminster, London, S.W.1, "The Use of Probe Rockets," C. A. Cross, 6 p.m.

HULL CHEMICAL AND ENGINEERING SOCIETY

Tues., Dec. 4th.—Church Institute, Hull, "Calcium Carbide Production," J. B. Moller, 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

To-day, Nov. 23rd.—BIRMINGHAM CENTRE: Regent House, St. Phillip's Place, Colmore Row, Birmingham, "Modern Applications of Plastics to Lighting Fittings," P. H. Collins, 6 p.m.
Mon., Nov. 26th.—BATH AND BRISTOL CENTRE: Royal Hotel, Bristol, "Lighting for Inspection," H. E. Bellchambers, 7 p.m.——LEEDS CENTRE: E.L.M.A. Lighting Service Bureau, 24, Aire Street, Leeds, 1, "My Most Interesting Lighting Job," S. Addison, J. W. Bessant, K. Graham and H. Laycock, 6.15 p.m.
Tues., Nov. 27th.—LONDON CENTRE: Lighting Service Bureau, 2, Savoy Hill, London, W.C.2, "Blackpool Illuminations," H. Carpenter, 6 p.m.

INCORPORATED PLANT ENGINEERS

Mon., Nov. 26th.—W. AND E. YORKS BRANCH: The University, Leeds, "Electronics in Industry," F. G. Totty, 7.30 p.m.
Tues., Nov. 27th.—S. WALES BRANCH: S. Wales Institute of Engineers, Park Place, Cardiff, "Inert Gas Welding Processes," Mr. Woollcott, 7.15 p.m.
Thurs., Nov. 29th.—MERSEYSIDE AND N. WALES BRANCH: Stafford Hotel, City Road, Chester, "Electrical Hazards," D. A. Picken, 7.15 p.m.——SHEFFIELD BRANCH: Grand Hotel, Sheffield, "Automation," 7.30 p.m.
Fri., Nov. 30th.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, "Canning," R. F. Rooke and Miss Christine Macnab, 7.30 p.m.
Tues., Dec. 4th.—LONDON BRANCH: Royal Society of Arts, John Adam Street, Adelphi, Strand, London, W.C.2, "Refrigeration and the Heat Pump," Sir Oliver Lyle, 7 p.m.

INSTITUTE OF FUEL

Wed., Nov. 28th.—Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, "The Cost in Britain of Air Pollution from Different Types of Source," R. S. Scorer, 5.30 p.m.

INSTITUTE OF MARINE ENGINEERS

To-day, Nov. 23rd.—MERSEYSIDE AND N.W. SECTION: Technical College, Birkenhead, "The Control of Steam Temperature in Marine Watertube Boilers," E. G. Hutchings, 7.15 p.m.
Mon., Nov. 26th.—W. OF ENGLAND SECTION: York House Hotel, George Street, Bath, "Passenger Liner with Engines Aft," R. K. Craig, 7.30 p.m.
Tues., Nov. 27th.—JOINT NUCLEAR MARINE PROPULSION PANEL: 85, Minories, London, E.C.3, "Some Safety Considerations of Nuclear Power Reactors," C. D. Boadle, 5.30 p.m.——N. IRELAND PANEL: Central Hall, College of Technology, Belfast, "Reheating as a Contribution to the Economy of the Marine Steam Turbine, with special reference to the Installation in T.S.S. 'Empress of Britain,'" A. W. Davis, 7.30 p.m.
Wed., Nov. 28th.—JUNIOR LECTURE: Technical College, Kingston-on-Thames, "Marine Diesel Engines," A. G. Arnold, 2.30 p.m.
Fri., Nov. 30th.—MERSEYSIDE AND N.W. SECTION JUNIOR LECTURE: Municipal College, Barrow-in-Furness, "Automatic Boiler Control," W. Young, 7 p.m.

INSTITUTE OF METALS

Tues., Dec. 4th.—OXFORD LOCAL SECTION: Cadena Cafe, Cornmarket Street, Oxford, Films of Scientific Interest, 7 p.m.
Thurs., Dec. 6th.—Chemical Department, Woodland Road, Bristol, Joint Meeting with the Chemical Engineering and Corrosion Groups of the Society of Chemical Industry, 6.30 p.m.

INSTITUTE OF PETROLEUM

Wed., Dec. 5th.—26, Portland Place, London, W.1, "Hydraulics of Drilling Mud Flow," Peter W. Cooke, 5.30 p.m.

INSTITUTE OF REFRIGERATION

Thurs., Dec. 6th.—Junior Institution of Engineers, Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Cooling Problems in High-Speed Military Aircraft," Miss B. Shilling, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Mon., Dec. 3rd.—SCOTTISH CENTRE: North British Hotel, Edinburgh, "Road and Rig Testing of Prototype Road Transport Vehicles and Their Components," J. H. Alden, 7 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Mon., Nov. 26th.—W. MIDLANDS CENTRE: Wolseley Engineering, Ltd., Witton, Birmingham, "Modern Equipment for Milk Production," H. S. Hall, 7.30 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Wed., Nov. 28th.—GRADUATES AND STUDENTS SECTION: Half-day Visit to the Metallurgical Plant of the Ford Motor Company, Dagenham.

INSTITUTION OF CIVIL ENGINEERS

To-day, Nov. 23rd.—BRITISH NUCLEAR ENERGY CONFERENCE: Central Hall, Westminster, London, S.W.1, Symposium of nineteen papers on the Calder Hall Plant, 10 a.m.
Tues., Nov. 27th.—STRUCTURAL AND BUILDING MEETING: Great George Street, Westminster, London, S.W.1, "The Analysis of Prestressed Concrete Structural Members and the Application of Recent Research," P. B. Morice, 5.30 p.m.
Thurs., Nov. 29th.—LECTURE ON THE CONSERVATION OF NATURAL RESOURCES: Great George Street, Westminster, London, S.W.1, "Metallic Corrosion and Conservation," W. H. J. Vernon, 5.30 p.m.
Fri., Nov. 30th.—YORKSHIRE ASSOCIATION: Grand Hotel, Sheffield, "The Analysis of Prestressed Concrete Structural Members and the Application of Recent Research," P. B. Morice, 6.15 p.m.
Tues., Dec. 4th.—WORKS MEETING: Great George Street, Westminster, London, S.W.1, "The Design and Construction of a Laboratory for Research in Underwater Ballistics," C. L. Champion, R. J. R. Hancock and W. Woolfson, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Wed., Nov. 28th.—SUPPLY SECTION: Savoy Place, London, W.C.2, "The Automatic Solution of Power-System Swing-Curve Equations," C. Adamson, L. Barnes and B. D. Nellist; "Electronic-Analogue-Computer Study of Synchronous-Machine Transient Stability," A. S. Aldred and P. A. Doyle; "Dynamic Operation of an A.C. Network Analyser," S. Kaneff, 5.30 p.m.——S.W. SCOTLAND SUB-CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Visit to Russia," J. S. Pickles and R. J. Rennie, 7 p.m.
Thurs., Nov. 29th.—ORDINARY MEETING: Savoy Place, London, W.C.2, "Differences of Opinion about Dimensions," R. O. Kapp, 5.30 p.m.
Mon., Dec. 3rd.—RADIO AND MEASUREMENT SECTIONS: Savoy Place, London, W.C.2, "Electronics and Automation: The Use of Nucleonic Devices," Dennis Taylor, 5.30 p.m.——S. MIDLAND CENTRE: James Watt Memorial Institute, Great Charles Street, Birmingham, "Crystal Palace Television Transmitting Station," F. C. McLean, A. N. Thomas and R. A. Rowden, 6 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Dec. 4th.—39, Elmbank Crescent, Glasgow, "Some Observations on Local Vibrations," A. J. Johnson and P. W. Ayling, 6.30 p.m.

INSTITUTION OF ENGINEERS-IN-CHARGE

Wed., Nov. 28th.—E.L.M.A. Lighting Service Bureau, 2, Savoy Hill, London, W.C.2, Presidential Address, The Rt. Hon. Lord Sempill, 6 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Tues., Nov. 27th.—BIRMINGHAM AND DISTRICT BRANCH: Exchange and Engineerng Centre, Stephenson Place, Birmingham, "Oil Firing of Central Heating Boilers," B. A. Williams, 6.30 p.m.——SCOTTISH BRANCH: 25, Charlotte Square, Edinburgh, "Assessment of Subjective Reactions in Heating and Ventilating Research," F. A. Chrenko, 7 p.m.
Wed., Dec. 5th.—Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, "Storage of Oil Fuel," T. Chippindale, 6 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Nov. 23rd.—BRITISH NUCLEAR ENERGY CONFERENCE: Central Hall, Westminster, London, S.W.1, Calder Hall Symposium, 10 a.m.
Sat., Nov. 24th.—MIDLAND GRADUATES SECTION: Visit to Dunlop Rubber Company, 7 p.m.
Wed., Nov. 28th.—AUTOMOBILE DIVISION: 1, Birdcage Walk, Westminster, London, S.W.1, Debate, "There is no Future for Laminated Plastics in Automobile Body Construction," 6.45 p.m.
Thurs., Nov. 29th.—EASTERN BRANCH: Hoffman Hall, Chelmsford, "The Application of Atomic Energy to Power Production," S. C. Curran, 7.30 p.m.——E. MIDLAND BRANCH: Technical College, Lincoln, "Crankcase Explosions: Development of New Protective Devices," W. P. Mansfield, 7.15 p.m.——N.W. BRANCH: Merseyside Film Institute Society Theatre, Bluecoat Chambers, Liverpool Technical Film Show Evening, 7 p.m.
Fri., Nov. 30th.—GENERAL MEETING IN CONJUNCTION WITH THE EDUCATION GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, "The American System of Education and Training of Mechanical Engineers," H. S. Arms; "The Education of Engineers in European Countries," S. J. Davies, 6 p.m.——WESTERN A.D. CENTRE: Royal Hotel, Bristol, "Heating and Ventilating Systems for Passenger Service Vehicles," T. R. Cave-Brown-Cave, 6.45 p.m.
Mon., Dec. 3rd.—N.E. BRANCH: Neville Hall, Newcastle upon Tyne, "A Standard Gas Turbine to Burn a Variety of Fuels," G. B. R. Feilden, D. R. Thorn and M. S. Kemper, 6 p.m.——LUTON A.D. CENTRE: Assembly Hall, Town Hall, Luton, "Experiences During Forty Years of Automobile Design," A. G. Booth, 7.30 p.m.

INSTITUTION OF NAVAL ARCHITECTS

Tues., Nov. 27th.—Institute of Marine Engineers, 85, Minories, London, E.C.3, "Some Safety Considerations of Nuclear Power Reactors," C. D. Boadle, 5.30 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Nov. 23rd.—S. WALES BRANCH: Institute of Engineers, Park Place, Cardiff, "The Training of Production Engineers," V. A. J. Chapman, 7 p.m.
Mon., Nov. 26th.—STOKE-ON-TRENT SECTION: Grand Hotel, Hanley, Stoke-on-Trent, "Cutting Tools: Application and Research," M. O. Short, 7.30 p.m.——MANCHESTER SECTION: Reynolds Hall, College of Technology, Manchester, "Modern Forging Practice," H. Hayes, 7.15 p.m.
Tues., Nov. 27th.—OXFORD SECTION: Ye Olde Bull's Head, Aylesbury, "Making Jigs, Tools and Moulds in Epoxide Plastics," P. G. Pentz, 7.30 p.m.——LUTON SECTION: W. H. Allen, Sons and Co., Ltd., Bedford, "Transfer Machines," 7.30 p.m.
Wed., Nov. 28th.—WESTERN SECTION: University Engineering Laboratories, University Walk, Bristol, 8, "Some Engineering Problems Associated with the Experimental Atomic Reactor," W. F. Wood, 7.15 p.m.——SHREWSBURY SECTION: Technical College, Oakengates, Shrewsbury, "Materials Utilisation," R. M. Evans, 7.30 p.m.——WORCESTER SECTION: Cadena Cafe, Worcester, "Process Development of Shell Moulding," J. Fallows, 7.30 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

To-day, Nov. 23rd.—MIDLAND COUNTIES BRANCH: James Watt Memorial Institute, Great Charles Street, Birmingham, "The Design, Manufacture and Full Scale Test on Formed Structural Sections," E. Griffin and J. M. Harvey, 6 p.m.
Fri., Nov. 30th.—YORKSHIRE BRANCH: Grand Hotel, Sheffield, "The Analysis of Pre-Stressed Concrete Structural Members and the Application of Recent Research," P. B. Morice, 6.15 p.m.
Tues., Dec. 4th.—NORTHERN COUNTIES BRANCH: Cleveland Scientific and Technical Institution, Middlesbrough, "The Advantages and Disadvantages of Structural Steelwork, Reinforced Concrete and Prestressed Concrete," Donovan H. Lee, 6.30 p.m.——N. IRELAND BRANCH: College of Technology, Belfast, "Tubular Steel Structures," R. G. Taylor, 6.45 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Nov. 23rd.—INFORMAL MEETING: Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Production of Flat Surfaces on Lapmaster Flat Lapping Machines," L. P. Hulin, 7 p.m.
Fri., Nov. 30th.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Annual General Meeting, 7 p.m.

LIVERPOOL ENGINEERING SOCIETY

Wed., Nov. 28th.—9, The Temple, 24, Dale Street, Liverpool, "Carborundum and Electric Furnace Graphite: The Work of Dr. Edward G. Acheson," E. A. Smith, 6 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

To-day, Nov. 23rd.—Engineers' Club, Albert Square, Manchester "Computers in Industry," B. Pollard, 6.45 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Fri., Nov. 30th.—Mining Institute, Newcastle upon Tyne, "The Nominal Cleavage Strength of Steel and its Importance for Welded Structures," T. Noren, 6.15 p.m.

ROYAL AERONAUTICAL SOCIETY

To-day, Nov. 23rd.—GRADUATES AND STUDENTS SECTION: 4, Hamilton Place, London, W.1, "The Effects of Kinetic Heating on Aircraft Structures," A. W. Kitchenside, 7.30 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., Dec. 3rd.—ORDINARY GENERAL MEETING: 12, Great George Street, Westminster, London, S.W.1, "The Chartered Surveyor in Local Government," H. E. G. Stripp, 5.45 p.m.

ROYAL SOCIETY OF ARTS

Mon., Nov. 26th, Dec. 3rd and 10th. THREE CANTOR LECTURES: John Adam Street, Adelphi, London, W.C.2, "Engineering Electronics," L. E. C. Hughes, 6 p.m.
Wed., Nov. 28th.—John Adam Street, Adelphi, Strand, London, W.C.2, "Air Conditioning of Buildings," J. S. Hales, 2.30 p.m.

SOCIETY OF ENGINEERS

Mon., Dec. 3rd.—Geological Society, Burlington House, Piccadilly, London, W.1, "The Submarine: Past, Present and Future," Sir Charles S. Lillicrap, 5.30 p.m.

SOCIETY OF INSTRUMENT TECHNOLOGY

Tues., Nov. 27th.—MAIN MEETING: Manson House, Portland Place, London, W.1, "Television Technique Applied to Observation and Control," J. D. McGee, 6.30 p.m.

WOMEN'S ENGINEERING SOCIETY

Thurs., Dec. 6th.—LONDON BRANCH: Hope House, 45, Great Peter Street, Westminster, London, S.W.1, Forum on Technical Education, 7 p.m.

Advanced Engineering Courses

The Application of Work Study to the Improvement of Process and Product. UNIVERSITY INSTITUTE FOR ENGINEERING PRODUCTION, "Southfield," 16, Norfolk Road, Edgbaston, Birmingham. Residential Executive Course, December 10th to 21st. Fee £50.